Foundry Energy Use Study & Conservation Manual

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INTRODUCTION

There is no longer any need to stress the importance of saving energy. Price increases and the realization that reserves of fossil fuels are finite and limited is an internationally recognized fact of modern life.

As a result, many governments, while searching for alternative energy sources and supporting new energy development programs, are taking direct action to conserve those resources that still remain. This workbook and the seminars that will be represented using this workbook are examples of this type of effort.

The foundry industry is a significant user of energy, and therefore, a natural candidate for efforts to save energy and improve efficiency by both governmental agencies and technical/trade associations. These efforts are designed to both improve the national energy position and improve the industry's efficiency and profitability.

Increased energy cost and the reduced availability of fossil fuels at certain times have provided the incentive to curb waste and to utilize purchased energy wisely.

Although energy use by foundries has gradually decreased on a per/ton basis in recent years, the foundry industry must continue to find ways to utilize energy more efficiently.

A. ENERGY UTILIZATION

The average foundry consumes approximately 70 to 80 percent of its total energy input in three principal areas of operation:

- Melting operations
- Heat treating operations
- Ladle heating operations

Areas of secondary importance for energy reduction measures are:

- Cleaning and finishing operations
- Mold and core making
- Pouring and shake-out

- Sand r laim system
- Dust and fume collection
- Compressed air systems
- Heating, ventilation and air conditioning systems
- Process cooling water systems
- Domestic hot water heating systems

Additional areas where energy conservation measures may be utilized:

- Building lighting systems
- Building weatherproofing
- System shut down during nonproduction periods
- Improvement in preventive maintenance programs

Long term process changes for significant energy reduction measures are:

- Scrap preheating
- Increasing yield
- Reduction in casting weight
- Reduction in holding furnace operations
- Preheating of castings
- Cogeneration systems

As stated above, approximately 70 to 80% of a foundry's energy input is consumed by melting, heat treat and ladle heating operations. Investment casting facilities and foundries in colder climates, however, would reduce this percentage due to the relatively large amounts of energy consumed for large process air conditioning systems and make-up air ventilation systems.

The following is a typical example of the energy mix and annual consumption rates in a steel foundry:

Item	Btu's per yr (x 10^6)	% overall energy
Natural Gas		
Heat treat	30,180	42
Ladle heating	16,490	23
Core drying and misc. gas	681	1
Subtotal	47,351	
Electricity		
Arc furnace (5 tons)	13,000	18
Induction furnace (250 kW)	1,000	1.5
Lighting	750	1.0
Major motors	7,000	10
Misc. Electrical	3,000	3.5
Subtotal	24,750	100
Foundry total	72,101	

NOTE: Above figures not applicable to nonferrous operations.

The above figures are purely hypothetical from the standpoint of yearly energy consumed by various processes; the overall energy utilization percentages are fairly representative of a steel foundry operation. The energy mix is approximately 66% gas and 34% electricity.

Based on the above observations this energy conservation workbook will address the three primary energy consuming processes, as previously mentioned, namely metal melting, heat treating and ladle preheating. An in-depth energy management analysis will be performed, by utilizing hypothetical mathematical models, to illustrate the potential energy savings and energy cost reduction measures possible by modification of existing equipment and/or changing basic process operations.

The principal areas for the "in depth" analysis will be as follows:

A. Gas Consuming Equipment

1. Heat treat furnaces:

(a) Installation of recuperators to preheat combustion air.

(b) Changing of burner system from atmospheric type to sealed - pressure regulated burners.

(c) Upgrading of heat treat furnaces to eliminate cracks and openings.

(d) Change conventional fire brick to ceramic fiber liners.

2. Crucible or reverberatory furnaces:

(a) Installation of recuperators to preheat combustion air.

(b) Change burner system.

(c) Replace castable refractory with vacuum - formed ceramic fiber.

(d) Provide charge access covers while furnace is in a holding mode.

(e) Install electric melt furnaces.

3. Ladle heating:

(a) Change burner from atmospheric to gas and compressed air with regulators.

(b) Install insulated covers

(c) Add insulation

(d) Change to electric ladle heating

B. <u>Coke Consuming Equipment (Cupola)</u>

1. Twin blast lined cupola

2. Hot blast lined cupola with recuperation

3. Hot blast water cooled cupola with recuperation and gas afterburners

4. Oxygen enriched cupolas

C. <u>Electrical Consuming Equipment</u>

1. Electric Arc Melting Furnace

(a) Off-peak melting

(b) Controlling demand

(c) Maximizing heat transfer

(d) Load management and optimization

(e) Installing water cooled blocks

2. Induction Furnace Melting (Coreless)

   (a) Off-peak melting

   (b) Improve operational methods

   (c) Improved furnace design

   (d) Oxygen-fuel assisted melting

   (e) Water cooling heat recovery

   (f) Maximization of melting capacity

3. Induction Furnace Melting (Channel)

   (a) Off-peak melting

   (b) Improve furnace design

   (c) Water cooling heat recovery

Energy conservation associated with other foundry processes (i.e., those that collectively represent approximately 20% of total energy input) will be discussed briefly, however, no attempt will be made to quantify possible energy savings.

PERFORMING AN "IN-HOUSE" ENERGY AUDIT

An efficient energy management program can only be implemented successfully if energy consumption habits of various foundry equipment is identified and recorded in a logical and workable format.

The result of active energy management is improved energy utilization; this invariably pays off in dollars, as well as making a major contribution to the national drive towards energy conservation.

To effect this result management should implement the following procedures:

1. Understand the plant's energy services and organize for day-to-day control.

2. Cost the energy services to determine incentives for potential profit.

3. Apply the same basic business principles to energy services that are used for other materials and supplies.

4. Encourage a long range energy plan that fits future plans of the foundry.

5. Initiate regular performance reports on energy usage.

Before the above work assignments can be put into effect, a comprehensive plant energy audit must be conducted. The following is a step by step procedure for an "in-house" audit.

1. Analyze gas, electricity and miscellaneous fuel bills for the past 12 months and convert all energy information into Btu's; use the following conversion figures to accomplish this:

   - 1 kWh = 3,412 Btu's
   - 1 MCF natural gas = 1,000,000 Btu's
   - 1 pound coke - 12,500 Btu's
   - 1 gallon of propane = 91,600 Btu's

   While tabulating annual consumption of energy sources into Btu's and dollars, an attempt should be made to determine which departments use how many Btu's of which fuel type (installation of in-house metering is essential for accurate data).

2. Analyze and record production schedules for the same time frame used for energy consumption. Total number of units in pounds produced by each department and the entire foundry should be recorded, also on a month to month basis. Make sure all information is recorded in units <u>or</u> weight and not a combination of both.

3. Physically inspect all equipment and identify systems or processes which are wasting energy and offer the best cost effective energy program. To determine equipment efficiencies, the following data should be recorded:

   (a) Total running time of equipment per day

   (b) Hourly energy consumption converted to Btu's

   (c) Operating temperatures

   (d) Flue and stack temperatures

   (e) Flue and stack airflow rates

   (f) Combustion data: i.e., CO_2 content of flue gas

   (g) Type and model number of gas burners

   (h) Ancillary motor horsepowers

   (i) Material through-put in pounds

   (j) Electrical demand profile and power factors

   (k) Include year of manufacturer

4. Utilization of data gathered under items 1, 2, and 3 will be sufficient to calculate:

   - Available heat to do useful work
   - Efficiency of equipment
   - Available heat for reclamation
   - Electric power utilization and efficiency
   - Percent energy savings

Section 3 will show examples of how to construct an energy flow diagram by utilization of mathematical models. Also, Section 3 will illustrate the necessary procedures required to calculate potential energy savings.

Construction of energy flow diagrams for various equipment processes will identify which areas offer the greatest energy saving potential. The final step is to make an economic evaluation in order to calculate the return on investment for capital improvements. Return on investment (ROI) will require the following input information.

- First Cost (Capital Expenditure)
- Annual Operating Costs
- Annual Fuel Savings
- Projected Fuel Price
- Estimated Life

A simple method for economic analysis is to calculate the payback period; this method utilizes the above basic data and will be used in this study.

SECTION 2
ENERGY USE IN FOUNDRIES

A. ELECTRICAL POWER

USE IN FOUNDRIES

As stated previously the typical usage of electrical energy in a steel foundry amounts to approximately 34% of the total energy used. The percentage could be much higher in foundries engaged in around the clock electric melting and minimal heat treat operations. Nonferrous foundries, on the other hand, will generally utilize less than 34% of electrical energy due to heavy gas melting.

Electrical energy is used in the following foundry operations:

- Melting metal
- Refining metal
- Holding melted metal
- Transporting melted metal
- Mixing and transporting sand
- Transporting cores and molds
- Cleaning and finishing (air compressors)
- Environmental control
- Miscellaneous equipment
- Lighting
- Heat treating

ELECTRICAL TERMINOLOGY

In this section reference will be made to various electrical units; to enable an understanding of each unit, the following identification is provided:

Pressure (Volt);	The volt, the pressure or potential difference required to produce one ampere in a resistance of one ohm. 1 kilo-volt (kv) = 1,000 volts.
Quantity (Coulomb);	The quantity of electricity conveyed by one ampere flowing for one second. Ampere hour, one ampere for one hour.

Power (Watt);	The watt is the power generated by a steady current of one ampere at a pressure of one volt. The kilowatt (kw) = 1,000 watts. One horsepower = 746 watts.
Energy (Joule);	The joule is the energy conveyed by one watt during one second, the kilowatt hour (kwh) is one kilowatt flowing for one hour.
Capacitance (Farad);	The farad is the electrostatic capacitance which will hold a charge at a pressure of one volt.
Current (Ampere);	The ampere, the rate of flow of a unvarying electric current.
Volt - Ampere;	The product of the rated load amperes and the rated range of regulation in kilovolts (kva).

MAXIMIZATION OF MELTING CAPACITY

In this and other sections of this study references and recommendations have been or will be presented for electrical energy conservation in the melting of metal. As previously stated, approximately 34% of the total energy used in a typical steel foundry is electrical. Of the 34% approximately 20% is used for melting or holding melted metal. The total kilowatts used for melting a ton of metal can only be reduced with improved furnace efficiency and operation, which will reduce the melt rate (tons/hour) and reduce energy consumption (kilowatt hours/ton). Areas where maximizing the melting capacity can save substantial energy are:

- Load factor should operate at high percent power utilization. The measure of the efficiency of utilization of electrical energy, taken on a monthly basis, is determined as the ratio of the average consumption in the month to the peak demand in that month.

- Electrical power costs per ton of metal melted will increase when "holding" metal for any length of time due to decreased power utilization. This condition is due to the thermal losses becoming proportionally larger when the furnace is in the idling mode, thus a melting operation should utilize full furnace power whenever possible and restrict holding time, thereby maximizing energy-saving potential.

- During slagging and charging of induction furnaces, it is necessary to open the furnace cover or lid to accomplish the intended actions. When the lid is open, thermal losses occur due to radiation from both the lid refractory and from the molten iron. The longer the "lid-open" time, the greater the loss of energy from the furnace. It follows that the energy consumption charge will increase with increased "lid-open" time, thus "lid-open" time should be no longer than absolutely necessary. The same principles apply to opening the roof on an arc furnace.

- The use of on-load solid-state stepless power controls has the following advantages:

  1. Furnace power can be maintained at a maximum level throughout the lining campaign.

  2. Furnace power can be phased back exactly as required by the plant demand control system.

  3. Furnace power can be phased back easily while tapping and charging which increases productivity.

- A good furnace operator can save energy in many ways. Fast charging and slagging of the furnace, with minimum cover "open time", will save the most heat energy. Bringing metal to temperature shortly before it is dispatched to the molding line and not keeping the metal in the furnace at its highest temperature for a prolonged period of time will result in less heat losses via refractory and spout; an added advantage is prolonged lining life. With an automatic molding line operation, it would be practical to deliver metal to the pourer in constant intervals, and deliver only the amount of metal he can pour in the molds rather than supply him with a constant amount of metal he cannot pour off before it cools down to the point where pigging is required.

- Some foundaries melt off-peak and hold so that pouring can be completed during the day-shift, thereby reducing demand charge.

MELT FURNACE IMPROVEMENT

Electric Arc Furnaces

The arc furnace is a refractory-lined vessel. At the beginning of the melting cycle it is filled by swinging aside the movable refractory lined roof and dumping in a charge of metallic scrap. The electrical energy needed to convert this charge to liquid metal is transmitted through several electrical distribution components, ending with the electrodes in the arc furnace (See Figure 2-5).

The furnace transformer takes the high transmission voltage and converts it into a lower operating voltage. The operator can choose from several operating voltage levels called "tap voltage".

Energy consumption, measured in kwh per ton, is fairly constant in most arc furnace operations, ranging from 450 to 550 kwh/ton of charge, depending on the scrap type and length of heat. There are few opportunities to decrease power consumption in electric arc furnace melting because the roof is off only for charging. However, heat can be recovered from the cooling water or furnace stack. Scrap preheating is an effective energy and electrode saver, as is the use of oxy-fuel burners.

Energy cost savings however can be substantial by applying the following procedures:

- Off Peak Melting

- Demand Limiting

- Demand Shifting

Energy conservation in arc melting is closely tied to power distribution, power demand regulation, furnace regulation and, most important, operating practices.

In a given furnace, the fastest heat usually not only produces the most tonnage but also converts energy most efficiently. The heat transfer at the arc should be optimized under various operating conditions. "Bore down" and "melt down" are normally best performed using maximum power for long arcs whose increased mobility speeds up the conversion of scrap to hot metal with minimum electrical losses. During meltdown, where the arc is surrounded by scrap, approximately 75 percent of all energy is used and thermal losses are at a minimum. During the refining period, when sidewalls are bare and only energy at a low power level is needed, to raise the bath temperature a few degrees, thermal losses are correspondingly higher.

Energy conservation in arc melting can be affected by many different variables. The most important ones are:

- arc furnace regulation — This system automatically lowers and raises the electrodes during the automatic mode of operation, always responding to the change in secondary current and voltage, and maintaining a pre-set distance between the electrode tip and the furnace charge. A regulating system which is not optimized can result in long and inefficient heats, requiring additional energy.

- power system characteristics — Primary power distribution switching by the supply and power company can change the existing short-circuit capacity and perhaps the primary voltage which in turn affects the arc length, resulting in excessive electrode consumption or excessive refractory erosion. This type of variable will also affect furnace productivity resulting in a higher consumption of energy.

- operating delays — Interruption in melting, scheduled or unscheduled, by unnecessarily lengthening the heat time, reduces furnace output and adds to the thermal losses in melting and can greatly increase the consumption of energy.

- human element — People are responsible for most major problems or improvements in energy conservation. Unnecessarily long, inefficient heats caused by many different interruptions always require additional energy. Energy can also be wasted by not using optimum voltage selection or by inappropriate changing power input, power factor and current due to misuse of electrical control devices. More and more arc furnace melt shops are placing increased emphasis on operator training in order to achieve better production and improved energy conservation.

A power profile or power program, which takes into consideration the full equipment capability, can be used with or without automated operation to greatly improve overall melting performance and energy management. This program defines precisely when to change the power input characteristic or when to recharge by noting the consumption of energy (kw/hr) in relation to weight and makeup of charge material.

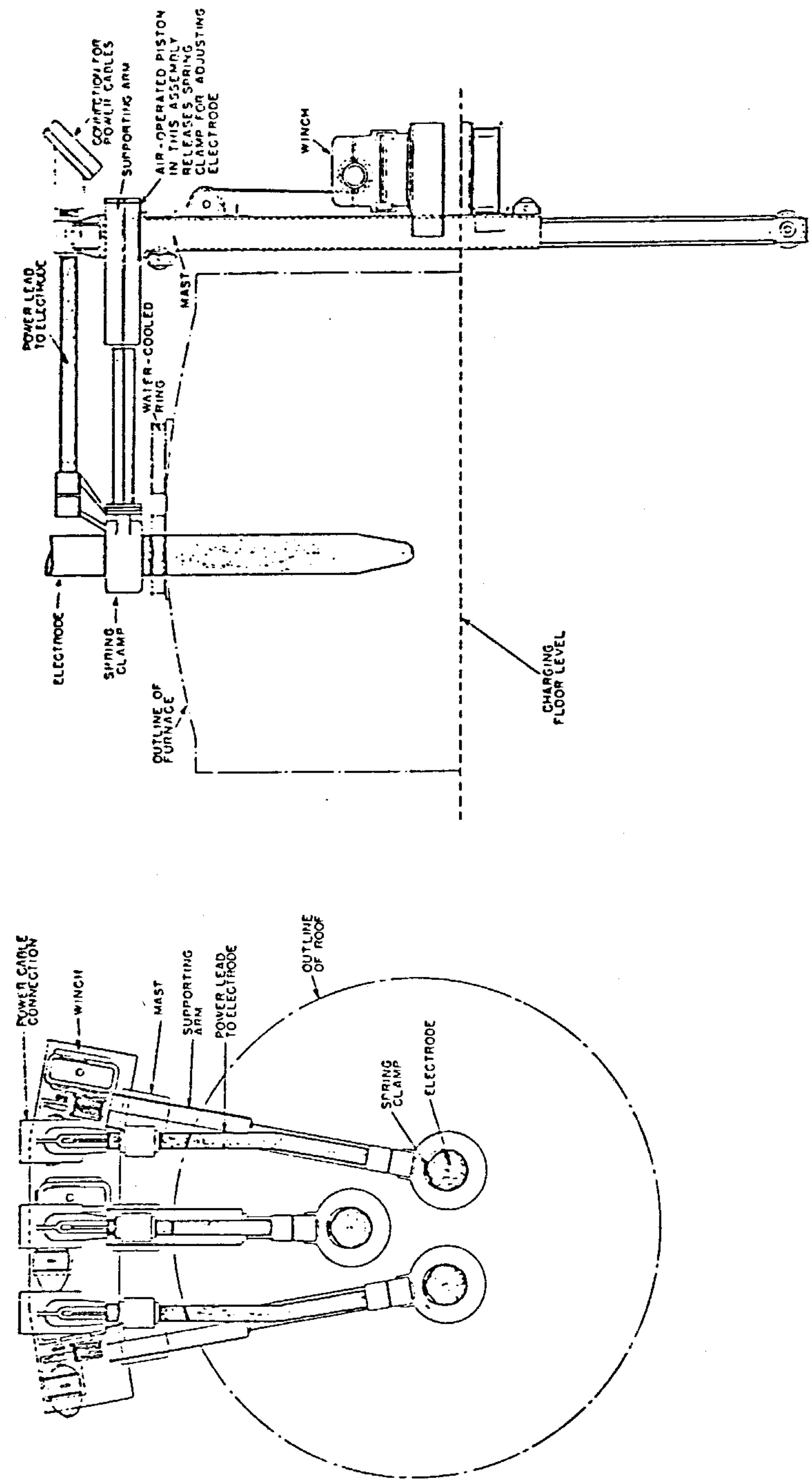


FIGURE 2-5. SCHEMATIC ARRANGEMENT OF THE ELECTRODES, THEIR SUPPORTING MASTS, AND THE ELECTRICAL LEADS FOR AN ELECTRIC-ARC STEELMAKING FURNACE

Induction Furnaces

Iron foundries that utilize electricity for melting use mostly coreless and channel type induction furnaces. All induction furnaces operate on the principle that when alternating current is passed through a coil, a magnetic field is created which induces eddy currents in a metal charge placed within that field. The degree of heating achieved is dependent on the rate of variation of the magnetic field (frequency) and on its intensity (power).

Channel furnaces are used for melting and duplexing, the requirements to always keep a heel in the furnace and the limitations of inductor power level limits their application as a primary melter. Electrical efficiency of an inductor is 94-95 percent, this is extremely high compared to coreless furnaces with a 76-81 percent efficiency.

Coreless furnaces loose approximately one fifth of the total energy consumed to the cooling water system, therefore considerable work has been done to improve furnace design.

The use of profile "D" (see Figure 2-6), for the power coil, reduces the penetration of magnetic flux lines through the outside corners which minimizes eddy current losses. Also, "D" profile allows the coil to be wound tighter with sufficient creepage distance which improves efficiency.

The cooling coils (Figure 2-7), on top and bottom, extract energy which should have gone into the melt. The use of newer castable backup refractory helps eliminate the need for cooling coils.

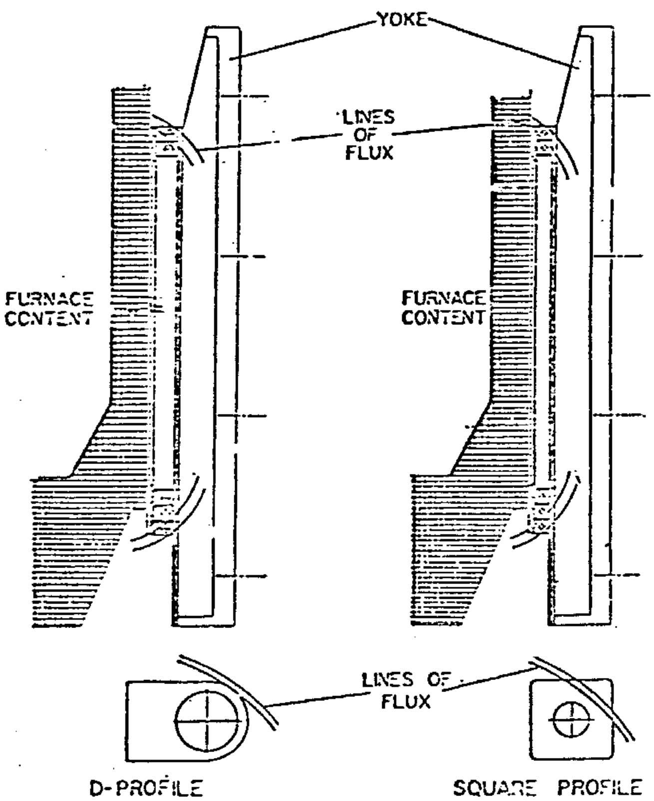


FIGURE 2-6

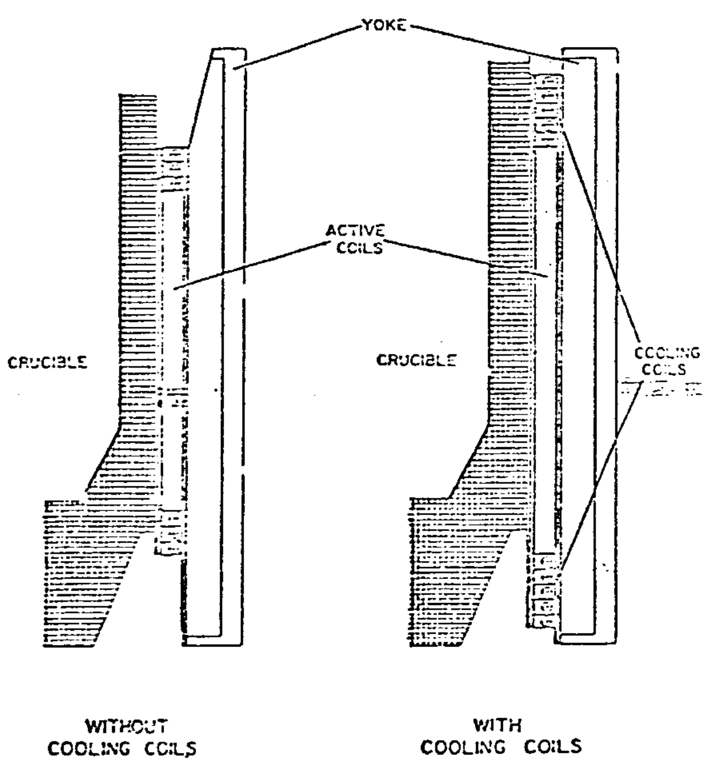


FIGURE 2-7

Electric Resistance Heated Reverberatory Melting Furnace (for Aluminum Melting)

Much like the fuel-fired furnace, the Electric Reverberatory Melting Furnace (ERMF) is constructed with an aluminum-resistant refractory lining and a structural steel shell. The total height of the furnace is much lower because the bath depth is more shallow, and less space is required above the bath. The furnace is heated by silicon carbide or other resistance elements mounted horizontally above the bath. Heat is transferred through direct radiation from the elements and radiation from the refractory roof and sides.

The second type ERMF metal melting system employs electric immersion type elements. The elements are inserted into silicon carbide tubes which are immersed into the molten aluminum. Through radiation, the element passes its heat to the silicon carbide tube and through conduction, the tube releases its heat into the bath. With the heating length of the element six inches from the bottom of the bath, temperature uniformity is good. With this immersion type, heat does not have to be transferred down through the bath from the surface.

Because the electric furnace does not need a flue, the heating chamber can be made almost airtight with the only heat loss being through the shell and from exposed radiant metal surfaces. A well is provided for charging of scrap and solids so there is no need to open the access door to the main chamber.

Metal Melting Loss

The metal loss from dross, due to oxidation, is approximately one percent for 11,000 lbs. of aluminum metal. At the present metal cost of $1.00 per pound this represents a very significant loss, and potential for savings.

Metal Quality

With the melting of aluminum metal, low gas levels and minimum oxide inclusions are a must. The only source of hydrogen gas in an ERMF is from the materials being charged into the furnace. Treatment of scrap and clean ingots keeps hydrogen gas at low levels.

Working Conditions

Working conditions around an ERMF are vastly superior to gas-fired reverberatory furnaces, the two major differences being noise and heat. ERMF are practically noiseless, while a bank of gas-fired reverberatory furnaces creates noise levels close to OSHA limits of 90 decibels. The heat loss from a bank of gas-fired reverberatory furnaces is extremely high and could amount to approximately 15 times more than the ERMF.

Furnace Covers

Uncovered charging and dip-out wells and bath radiate 20,000 Btu/ft^2/hr vs only 500 Btu/ft^2/hr for a covered well, a factor of 40 times. The importance of well covers in a holding situation cannot be over-emphasized.

Graphite Rod Holding Furnace

As the graphite rod holding furnace is not a primary melting furnace, this furnace will not be addressed with regards to cost savings. The efficiency and utilization of energy input to metal holding is high. The power factor is maintained at near unity. With this type of unit not much design improvement is possible.

Ladle Metallurgy

In recent years, a great deal of emphasis has been placed on the concept of "Clean Steel Technology" in the steel foundry industry. Considerable research funding has been applied to the definition and production of clean steel. From a foundryman's standpoint, "Clean Steel" generally means low levels of sulfur and phosphorus, low gas content, and a minimum of inclusions, both macro and micro. These requirements are, of course, driven by the marketplace and these trends will continue.

These challenges have been met in the basic steel industry through the use of various ladle refining technologies. These processes, however, have been difficult to transfer directly to the foundry industry because of the small size ladles used in the typical foundry. These ladles are generally 5-ton capacity and smaller. Heat losses in small ladles are proportionally greater than for large ladles which severely restricts the time available for ladle treatments. In addition, a reagent to be used for desulfurization or inclusion control should have maximum time available for complete dissolution which implies introduction to the ladle at the very bottom and a sufficient depth of metal to allow dissolution during the time available for flotation to the upper surface. Small foundry ladles often do not have sufficient depth to allow this to occur.

A further consideration is the nature of the slag cover on the ladle. Slags that are effective in lowering the sulfur and oxygen content often have relatively high melting points and tend to crust and be non-reactive under the conditions described above. In order to overcome these problems, a good deal of work is in progress to develop viable foundry size ladle furnaces that would compensate for the heat losses and allow sufficient time for effective refining.

It is apparent from the above discussion that these ladle refining processes all result in increased processing time in the ladle and temperature losses that at times may be quite severe. One method commonly used to compensate for these heat losses is to tap the heat at a considerably higher temperature than otherwise required. However, to carry out extensive ladle refining operations without some sort of reheating would likely result in temperature losses that would be too great to be compensated simply by using a higher tap temperature. In addition, the use of a higher tap temperature results in excessive energy consumption, excessive refractory wear and unnecessary reoxidation.

The above considerations, then, have led to the interest in developing a foundry sized ladle furnace capable of compensating for heat losses during refining, melting substantial alloy additions, and controlling (increasing if necessary) the pouring temperature.

Another feature of a foundry ladle furnace is that it is capable of increasing productivity by performing a major part of the total heat cycle in a separate vessel. This allows the primary melting unit to perform the function that it was designed for, that is, melting. Most melting furnaces, particularly arc furnaces, are very inefficient refining vessels due to shape, power input levels, and lack of stirring capability. It is for this reason, that refining is more efficiently conducted in a separate unit that is specifically designed and equipped to perform these functions. The use of this concept can increase productivity in the melting operation by approximately 20-30 per cent.

Plasma Fired Cupola

A cupola is a vertical cylindrical shaft furnace which is conventionally used in the foundry industry for the production of cast iron. One of the main features of such a furnace is counter-flow preheating of the charge material by upward-flowing hot gases. Because the conventional cupola relies on the combustion of metallurgical coke for its source of energy, the velocities of the gases are high. To avoid entrainment of scrap particles in the flowing gas stream, briding and oxidation of small size scrap must be avoided, limiting the flexibility of choice of melt materials. Finer materials such as turnings and borings, which are much cheaper than conventional scrap, cannot be fed directly into the cupola unless they are first briquetted, a costly and inconvenient process.

In order to circumvent these problems, a plasma fired cupola has been jointly developed by Westinghouse, Modern Equipment, General Motors, and EPRI. This cupola, a more-or-less conventional cupola shaft furnace fitted with plasma torches, has the distinct advantage of providing the energy for iron melting independent of coke combustion. Since the volume of plasma gas needed to introduce this energy is much smaller than the volume of coke combustion products, the velocities of the gases rising in the plasma-fired cupola are relatively low. Therefore, low-cost charge materials like borings and turnings can be fed directly into the cupola.

Beyond allowing the use of low cost charge materials, the plasma-fired cupola has other key benefits. The oxidation of alloy elements (silicon, chromium, manganese, etc.) and their corresponding loss to the slag is a costly characteristic of conventional cupolas. By using a plasma super-heated blast at the tuyere level of the cupola, a faster reaction rate between the carbon of the coke and the oxygen of the blast air is realized, and high CO/CO_2 ratios result. This produces a highly reducing atmosphere which reduces the oxidation losses. Therefore, the recovery of the alloy elements is increased. Moreover, the temperature in the bottom section of the cupola can be significantly increased. With this, reducing conditions can be established to a level sufficient that silicon can be produced through the reduction of silica. Procedures such as this are not practical in conventional cupolas. They apply the combustion of coke, oil or gas and attain operating temperatures of the order of 3000° F maximum. With plasma technology, temperatures in the reaction zone can reach 10,000° F.

Another economic benefit of the plasma-fired cupola is the increase in productivity due to the significantly higher operating temperatures. The melting capacity of a conventional cupola can be increased by as much as fifty percent by using plasma as an energy source. Further, the start-up of the plasma-fired cupola has been found to be much faster than the conventional cupola, thereby reducing labor cost.

The environmental benefits of the plasma-fired cupola are also noteworthy. Because of the availability of electrical energy for the melting of the iron, coke consumption and thus the generation of combustion products, can be minimized. As a result, levels of environmental emissions are reduced proportionately. Coke is required in the plasma-fired cupola to provide a source of carbon for the iron and to provide for the proper porosity of the charge material as it moves downward through the cupola shaft. It also contributes to the preheating of the upward flowing gases. Coke combustion also provides a portion of the energy required for the iron melting. Using plasma, the proportions of electrical energy and coke consumption energy can be optimized to achieve the lowest cost production on hot metal.

The initial experimental work involved a pilot-scale test cupola using a single 1500 kW Westinghouse plasma torch at the Westinghouse Plasma Center located at the Waltz Mill site in Madison, Pennsylvania. Based on the results of this work a commercial installation was constructed at the General Motors Central Foundry Division plant in Defiance, Ohio.

This cupola, called the Plasma Melter, began life as a conventional 13-ft.-diameter cupola and was retrofitted with six 1.5 megawatt direct current Westinghouse plasma torches in the tuyere section of the cupola. Blast air volume was reduced from 25,000 cfm for conventional operation to 10,000 cfm in the Plasma Melter.

The Plasma Melter produced iron for its first castings in March 1989, and is now operating on a two-shift basis with electrodes inspected and maintained over the weekends. The rated capacity of the Plasma Melter is 45 tons/hour.

This installation has been economically justified on the basis of being able to use in-house turnings and borings as melt stock without costly briquetting. These economics may not apply to all foundries, however, this technology should find wide application and contribute to the profitability of many organizations.

Plasma Assisted Cupola

A somewhat different approach to the use of plasma heating with cupola melting is the "Plasma Assisted" system developed by Aerospatiale in France. In this approach, a conventional hot-blast cupola was retrofitted with a plasma torch located in the wind box to serve as a supplemental heating device.

A demonstration study was conducted at the Sept-Fons (France) foundry of Automobiles Peugeot by fitting a portable, 2 MW plasma torch to an existing 20 ton/hour hot-blast cupola. The current installation produces gray cast iron for mass-produced parts such as cylinder blocks, hub-drums, disc brakes and exhaust manifolds. Hot blast temperature (without plasma assist) ranges from 660-930^{0} F depending on the blast rate.

The test campaign was run using hot-blast temperatures ranging from 1650-2370^{0} F, again depending on the blast rate. The principal advantage realized by this approach was the ability to use a higher percentage of low-cost steel scrap in the charge. In addition, Peugeot reported savings in coke consumption. Further, the use of oxygen enrichment was not required resulting in further savings. Based in Peugeot's figures, a payback period of 2.2 years was realized. The generally favorable results of this demonstration effort resulted in the commissioning of a 4 MW production unit in 1988. Operating results of this installation have not yet been reported in the literature.

Additional study of this approach is required, and it appears that the use of a lower preheat temperature may allow a lower cost installation as far as refractories, insulation, etc. are concerned. This, in turn, would shorten the payback period - perhaps significantly. This approach has considerable merit and should be studied further with the goal of optimizing the relationship between preheat temperature and installation/ operating costs.

B. NATURAL GAS AND EQUIVALENT FOSSIL FUELS

USAGE IN FOUNDRIES

As stated previously in this study, a typical steel foundry uses up to 66% of its fuel energy input for gas fired equipment. In most foundries overall efficiency of melt furnaces, heat treat furnaces and ladle heating is about 20% or even lower which, in relative terms, means that for every 100 units of gas energy input only 20 units are utilized to heat the product, the remaining 80 units are expended in furnace losses and exhaust losses, Figure 2-8.

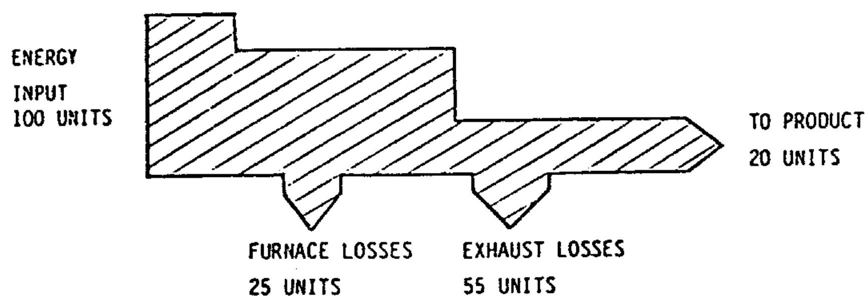


FIGURE 2-8 PROCESS ENERGY FLOW DIAGRAM

By drawing a process energy flow diagram, as illustrated above, one can actually see the major areas of concern. Once the above information has been developed, an energy flow diagram of the same process under ideal conditions can be developed. By comparing the actual diagram to the ideal, one can further improve chances of maximizing energy savings while minimizing capital investment.

While energy recovery is usually the first area addressed for energy conservation, a closer look at the problem will usually prove that improvements in the combustion air to gas ratio, furnace pressure controls, insulation, and refractory produce the bulk of the available energy savings at the least capital cost.

TERMINOLOGY AND THE BILL

Unlike electricity, gas utility bills are very simple to read, the following is a typical example of a monthly gas utility bill:

1

SERVICE PERIOD	
06-18-79	07-18-79

SERVICE ADDRESS: ________________

2

RATES	THERMS
GN-1	
GN-2	17,667
GN-3	22,486
TOTAL	40,153

$ 9,760.09

3

METER NUMBER	METER READINGS PREVIOUS	PRESENT	DIFFERENCE	BILLING FACTOR	THERMS
2345678	917920	955980	38060	1.055	40,153

BOX 1 is the service period on a monthly basis.

BOX 2 is the rate schedule and terms used.

Gas company rates are based on the following priority schedule:

- GN-1 is for residential and small industrial users consuming less than 100,000 cubic feet of gas per day.
- GN-2 is for industrial users consuming over 100,000 cubic feet per day and who have standby fuel capability.

Box 3 shows the actual months consumption in cubic feet of gas.

The billing factor is the actual heat content of the gas. (Can vary depending on location).

The final column is the amount of therms used for the month.

Meter units are 100 cu. ft. (i.e., example equals 3,806,000 cu. ft.)

Our hypothetical bill is interpreted as follows:

1.	Gas consumption @ GN-2 rate	=	17,667 therms
2.	Gas consumption @ GN-3 rate	=	<u>22,486</u> therms
3.	Total gas consumption	=	40,153 therms
4.	Difference in meter readings	=	3,806,000 cu ft
5.	BTU content of gas	=	1,055 BTU/cu ft
6.	Amount of therms used per month $= \dfrac{3{,}806{,}000 \times 1{,}055}{*\ 100{,}000}$	=	<u>40,153</u> therms

* 1 therm - 100,000 BTU

Actual BTU's consumed = $40{,}153 \times 10^5$ BTUs

IN PLANT METERING

The monthly gas utility bills show how many Btu's have been expended to produce a product, what the bill does not tell you is where the Btu's were used in a particular gas consuming process.

As the nation's energy requirements grow, the Foundry Industry can expect to pay even more for gas in future years. Foundries that will remain dependent upon gas for their production processes will be placing even greater emphasis on in-plant conservation efforts in order to achieve maximum production efficiency from this increasingly expensive fuel.

Cost allocations, within departments, and fuel surcharges to customers will become commonplace. Close monitoring of allocated supplies will become a necessity in energy management.

The basic and most important tool in energy management is an energy monitoring system. Before energy can be saved, an accurate metering system must be established in the foundry to determine exactly how and in what quantities, energy is being used, considerable savings can be realized almost immediately from the data derived from an energy audit using in-plant metering.

Gas consumption monitoring can also be advantageously used to control oven or furnace temperatures and prevent over-temperature damage. Also equipment problems can be detected before they cause emergency shut down.

Measuring fuel consumption alerts maintenance crews to a variety of potential problems such as:

- Leaking fuel lines

- Faulty temperature measuring devices
- Faulty relief valves
- Excessive burner cycling
- Warped furnace doors
- Deteriorating furnace insulation

A relatively low cost monitoring device is the "Annubar". This device is a primary flow sensor designed to produce a differential pressure that is proportional to flow. The flo-tap annubar can be inserted and removed from operation <u>without system shut down</u>.

Annubar can be interfaced with secondary devices, a standard flow meter is available for rate of flow indication. It can be used as a portable meter or permanently mounted.

Annubar connected to a differential pressure transmitter (Electric or Pneumatic) is used with a variety of standard secondary equipment for totalizing, recording or controlling complex systems.

OBTAINING A COMBUSTION ANALYSIS

In order to determine the operating efficiency of melt and heat treat furnaces it is imperative that a flue gas analysis be made. One of the best ways available for obtaining a flue gas analysis for CO_2 and O_2 is the use of a combustion analyzer.

In most actual combustion processes the determination of correct air-fuel ratio cannot be made by direct measurement of entering air, since various leakages through auxiliary openings will be responsible for a substantial increase in total air over that metering at the burner, thus for practical purposes the air-fuel ratio must be determined by calculation from data available, hence the combustion analyzer.

The flue gas data resulting from a combustion analysis are used with suitable charts (see Section 3) for determining the percent excess air and, together with the information on flue gas temperatures, to determine the heat lost in the stack.

TEMPERATURE MEASUREMENTS

Accurate measurement of high temperatures is one of the most critical factors in determining equipment performance and process efficiencies of energy consumption in foundries, high temperatures are defined as those between 700 and 3,500° F.

Sensors used to measure elevated temperatures are classified as either contact or non-contact. Contact sensors include thermocouples, resistance temperature detectors, bimetallic thermometers, thermistors, and filled systems. Non-contactors include optical and radiation pyrometers. Thermocouples are used in a large number of the applications in industrial plants.

Portable thermocouples of various designs are available. The instruments are compact, lightweight, and battery powered, and they can easily be carried around the plant to measure process or equipment temperatures easily. Most models have a variety of interchangeable thermocouples sensors and multiple temperature selector switches to provide maximum versatility. (See table 2-I for comparisons).

TABLE 2-I. COMPARISON OF COMMON THERMOCOUPLES

Type	Usable Temperature Range	Advantages	Restrictions
Type J (Iron-constantan)	-300 to 1600 F	Comparatively inexpensive. Suitable for continuous service to 1600 F in neutral or reducing atmospheres.	Maximum upper limit in oxidizing atmosphere is 1400 F, because of the oxidation of the iron. Protection tubes should be used above 900 F. Protection tubes should always be used in a contaminating medium.
Type K (Nickel, chromium-nickel, aluminum)	0 to 2500 F	Suitable for oxidizing atmospheres. In higher temperature ranges, provides a more mechanically and thermally rugged unit then platinum or rhodium-platinum, and longer life than iron-constantan.	Especially vulnerable to reducing atmospheres, requiring substantial protection when used.
Type T (Copper-constantan)	-300 to 700 F	Resists atmospheric corrosion. Applicable in reducing or oxidizing atmospheres below 600 F. Stability makes it useful at subzero temperatures. Has high conformity to published calibration data.	Copper oxidizes above 600 F.
Type E (Nickel, chromium-constantan)	-300 to 1600 F	Has high thermoelectric power. Both elements are highly corrosion-resistant, permitting use in oxidizing atmospheres. Does not corrode at subzero temperatures.	Stability is unsatisfactory in reducing atmospheres.

TABLE 2-I (CONTINUED)

Type	Usable Temperature Range	Advantages	Restrictions
Type S (Platinum, 10% rhodium-platinum)	0 to	Usable in oxidizing atmospheres. Provides a higher usable range than Type K.	Easily contaminated in other than oxidizing atmospheres.
Type R (Platinum, 13% rhoduim-platinum)	2700 F	Frequently more practical than noncontact pyrometers. Has high conformity to published calibration data.	
Type B (Platinum, 30% rhodium-platinum, 6% rhodium)	1600 to 3100 F	Better stability than Type S or R. Increased mechanical strength. Usable at higher temperatures than Type S or R. Reference-junction compensation is not required if junction temperature does not exceed 150 F.	Available in standard grade only. High-temperature limit requires the use of alumina insulators and protection tubes. Easily contaminated in other than oxidizing atmospheres.

BURNER COMBUSTION EFFICIENCY

Conserving fuel in melting, heat treating and ladle heating operations is a complex operation. It requires careful attention to the following:

- Refractories and insulation
- Scheduling and operating procedures
- Preventative maintenance
- Burners
- Temperature controls
- Combustion controls

Providing the correct combustion controls will increase combustion efficiency measurably. Complete combustion of Natural Gas Yields:

(a) Carbon dioxide

(b) Water vapor

If gas is burned with the chemically correct amount of air, an analysis of the products of combustion will show it contains about 11 to

12% CO_2 @ 20-22% water vapor. The remainder is nitrogen, which was present in the air and passed through the combustion reaction essentially unchanged.

If the same sample of natural gas is burned with less than the correct amount of air ("rich" or "reducing fire"), flue gas analysis will show the presence of hydrogen and carbon monoxide, products of incomplete combustion. Both of these gases have fuel value, so exhausting them from furnaces is a <u>waste</u> of fuel. (See Figure 2-9)

If more than the required amount of air is used (lean or oxidizing flame), all the gas will be burnt but the products of combustion will contain excess oxygen. This excess oxygen is an added burden on the combustion system - it is heated and then thrown away thereby <u>wasting</u> fuel.

The following steps should be taken to upgrade burner and combustion controls:

1. Use sealed-in burners. Make all combustion air go through the burner - open cage type burners are very inefficient.

2. Use power burners. Inspirator or atmosphere burners have very poor mixing efficiency at low inputs, especially if gas pressure is low.

3. Install a fuel/air ratio control system.

<u>PREMIX BURNER SYSTEMS</u>

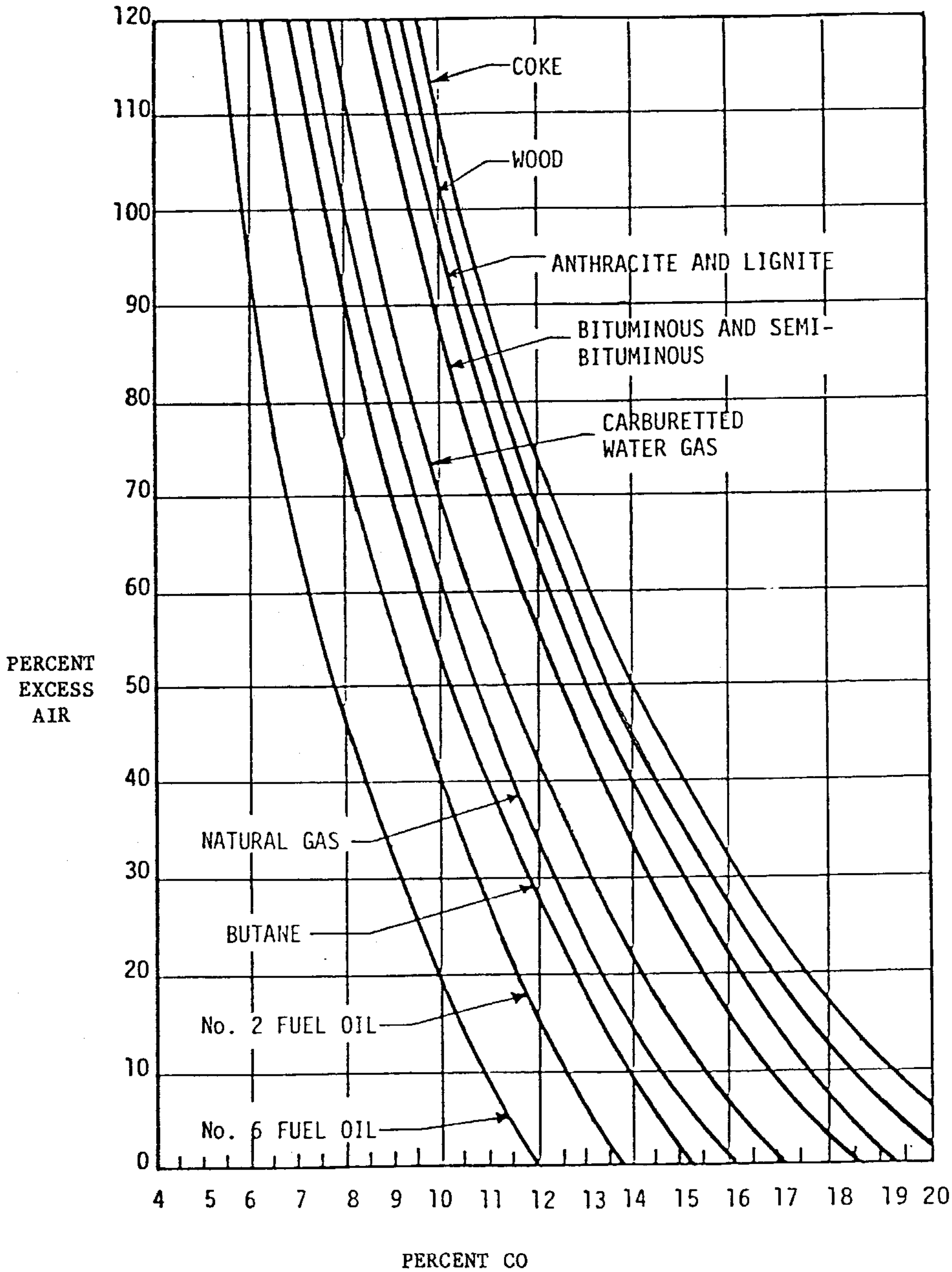
Premix burner systems commonly use a venturi mixer known as an aspirator or proportional mixer. Air from the blower passes through the venturi, creating suction on the gas line and drawing in the correct amount of gas at reduced firing rates, air flow is cut back, reducing suction on the gas line, and the amount of gas drawn into the mixer drops in proportion to air flow. Aspirator systems are fairly simple to adjust and maintain accurate fuel/air ratios over wide turndown ranges, but their use is limited to premix burners. (Figure 2-10)

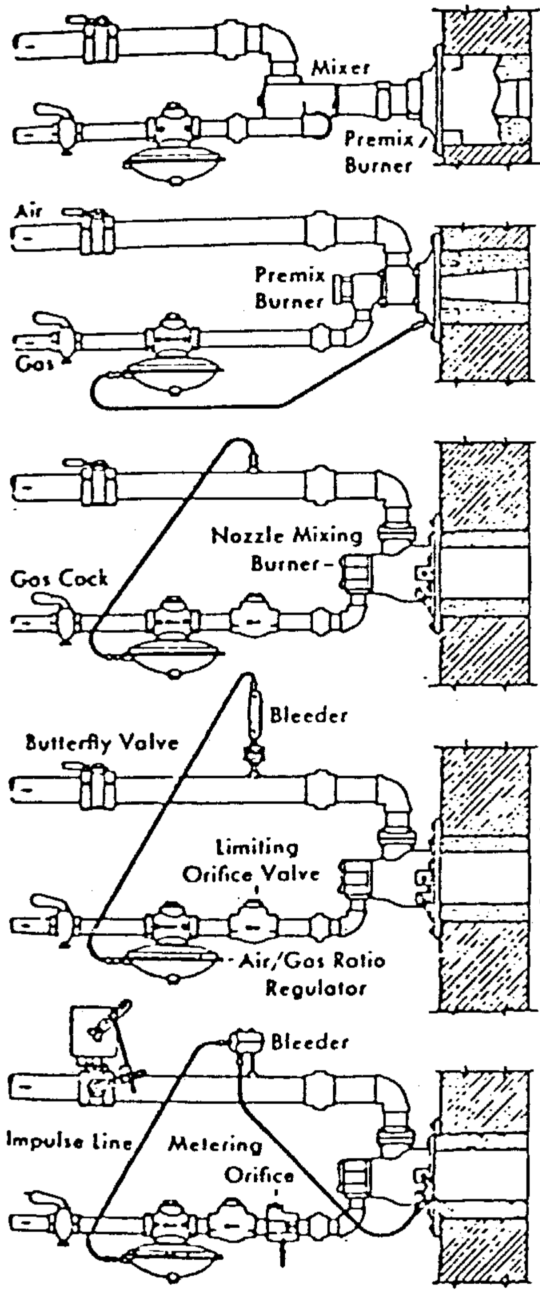
<u>NOZZLE MIX BURNERS</u>

Nozzle mix burners used with a Ratio Regular System is widely used for industrial furnace applications. Orifices are installed in the gas and air lines to a burner and then adjusted so that air and gas are in correct burning proportions when pressure drops across the orifices are equal. Once the orifices are set, they will hold the correct air/gas ratio as long as the pressure drop remains the same, no matter what firing rate. Ratio Regulator systems have good accuracy and are fairly easy to adjust. (Figure 2-10)

On large furnaces where fuel consumption is extremely high, or on furnaces where very close control of the atmosphere is required, extremely accurate fuel/air ratio control is vital, both for fuel economy and product quality. On these installations hydraulic or electronic flow controls are often used.

FIGURE 2-9 PERCENT EXCESS AIR FROM CO_2 READING





a. Premix Burner (gas suction proportional to air flow). Combustion chamber pressure steady at zero.

b. Premix Burner (gas suction proportional to air flow). Combustion chamber pressure fluctuating.

c. Nozzle Mixing Burner. Gas pressure = or greater than air pressure. Combustion chamber pressure steady or fluctuating.

d. Nozzle Mixing Burner. Gas pressure less than air pressure. Combustion chamber pressure steady at zero.

e. Nozzle Mixing Burner. Gas pressure less than air pressure. Combustion chamber pressure fluctuating. Motor-operated air input control valve and gas metering orifice shown here could also be used in a, b, c and d.

FIGURE 2-10 TYPICAL GAS/AIR REGULATOR HOOK-UP

These systems feature fixed orifices in both gas and air streams, and these orifices are sized to pass proportional amounts of gas and air at equal pressure drops, pressure drop signals are fed to a ratio controller which compares them. One of the outstanding features of this system is that the fuel/air ratio can be adjusted by turning a dial. Since a burner can be thrown off correct gas ratios by changes in ambient air temperature and humidity, this ratio adjustment feature permits the operator to set the burner back to peak operating efficiency with very little effort.

On multiple burner furnaces, the combustion products of all burners mix together before they reach the flue gas sampling point (Furnaces should have manifolded flue gas outlets in order to obtain common sampling point for flue gas analysis). If, for example, some of the burners are unintentionally set lean, and others rich, the excess air from the lean burners could consume the excess fuel from the rich burners, producing flue gas with ultimate CO_2 and practically no free oxygen or combustibles. Samples of these gases could be misleading and show correct air/gas ratio, when in fact they are not. Also if a burner is set rich and the excess combustibles in the flue gases find air in the stack and burn there, flue gas analysis will again suggest that the burner is properly adjusted.

To overcome the problem of misleading flue gas analysis in multi-burner furnaces, metering orifices should be installed on the gas lines to each burner. If pressure drops across all orifices are identical, gas flow to each burner will be the same.

FURNACE PRESSURE CONTROLS

Furnace Pressure Controls will afford additional energy savings, particularly on top-flued furnaces. If a furnace operates under negative pressure, cold air is drawn into it through badly fitted doors and cracks. This cold air has to be heated, adding to the burden on the combustion system and wasting fuel. If the furnace operates at high positive pressure, flames will sting out through doors, site ports and other openings, damaging refractories and buckling shells. Ideally a neutral furnace pressure overcomes both these problems.

Automatic furnace pressure controls maintain a pre-determined pressure at hearth level by opening or closing dampers in response to furnace pressure fluctuations.

In summation; good fuel/air ratio control equipment and automatic furnace pressure controls are two useful weapons for combating gas energy wastage in heating operations.

Properly applied, they also offer the side benefits of improved product quality and shortest possible heating cycles.

FURNACE EFFICIENCY

Conventional refractory linings in heating furnaces can have poor insulating abilities and high heat storage characteristics. Basic methods available for reducing heat storage effect and radiation losses in melt and heat treat furnaces are:

1. Replace standard refractory linings with vacuum-formed refractory fiber insulation material.

2. Install fiber liner between standard refractory lining and shell wall.

3. Install ceramic fiber linings over present refractory liner.

The advantages of installing refractory fiber insulation are:

- Refractory fiber materials offer exceptional low thermal conductivity and heat storage. These two factors combine to offer very substantial energy savings in crucible, reverberatory and heat treat furnaces (documented savings - 35% or better).

- With bulk densities of 12-22 lbs./cu ft, refractory fiber linings weigh 8% as much as equivalent volumes of conventional brick or castables.

- Refractory fibers are resistive to damage from drastic and rapid changes in temperature.

- Fiber materials are simple and fast to install.

- The density of fiber refractory is low, so there is very little mass in the lining, therefore much less heat is supplied to the lining to bring it to operating temperature. This results in rapid heating on the start-up. Conversely, cooling is also rapid, since there is less heat stored in the lining.

- More comfortable working environment is attainable due to lower shell surface temperatures.

The basic design criteria for fiber lined crucible furnaces are the same as used for furnaces lined with dense refractories. Two rules should be followed:

1. The midpoint of the burner should be at the same level as the bottom of the crucible, and the burner should fire tangentially into the space between the crucible and lining.

2. The space between the outside of the crucible, and the furnace lining near the top should be about 10% of the crucible diameter.

Crucible furnaces can be constructed using a combination of fiber with dense refractory or almost entirely out of fiber. Increasing the proportion of fiber will increase the energy savings and maximize the other benefits previously listed.

Fiber materials are available in varying thicknesses, suitable for a complete monolithic installation, and composition to handle 2,400° F, 2,600° F, and 2,800° F.

The higher temperature compositions contain high alumina fiber, which lowers the amount of shrinkage at elevated operating temperatures.

FURNACE COVERS

If preheating of combustion air utilizing furnace flue gas temperatures is contemplated, installation of furnace covers is mandatory. The difficulty in the past, in the fabrication and use of furnace covers, has been the problems of thermal shock and spalling, materials available today, such as refractory fiber, have eliminated these problems.

In addition to technological advantages of fiber insulations, industry has also developed the capability of vacuum forming these materials over a variety of metallic support structures. Fiber insulation can be formed over either expanded metal or angle iron frames, or both, with V-type anchors attached. The anchors are made from high temperature alloys, holding the fiber to the metallic support structures to provide an integral, fully secured assembly. No part of the anchor system is exposed to excessive temperatures, this eliminates attachment problems for ladle pre-heaters, crucible furnace covers, and induction furnace covers. Installation of furnace covers improves the thermal efficiency of the process by approximately 50%.

CRUCIBLE POT AND REVERBERATORY FURNACES

Non-Ferrous Foundries utilize three basic furnace types for melting and holding. They are:

- Gas fired crucible
- Gas fired reverberatory
- Electric reverberatory

The stationary crucible furnace is primarily used for aluminum, copper, and brass alloys. Its versatility in allowing alloy changes makes it a desirable furnace for small foundries where such metal changeover is necessary. Combustion burners are located so the flame is tangential to the crucible in order to avoid direct flame impingement against the crucible wall. Biggest disadvantage, other than thermal efficiencies, are short crucible life.

Fuel fired reverberatory furnaces are usually chosen when melt rate and/or capacity is such that a crucible would be too small. The reverberatory is direct fired from either the roof or sidewall with gas, propane, or oil burners (for the purpose of this study the relative cost per BTU is assumed as being equal). The heat is transferred to the bath by a combination of convection and radiation.

UPGRADING GAS FIRED FURNACES

1. Replace brick or castable refractory with vacuum-formed refractory fiber on gas fired crucibles.

   Example -- Arrow Casting and Development Co., in Santee, California, installed fiber liners on two - 425 lb. crucibles - documented 35% saving in fuel. They can now produce a melt in one hour from cold start as compared to 2-1/2 hours with conventional refractory liner-payback period - 6 months.

   Other advantages:

   - Faster turn around time at reline time
   - Lower shell temperatures (500 to 350° F)

2. Add fiber insulated liner between standard refractory liner of shell casing.

3. Update combustion controls (se burner combustion efficiency discussion)

4. Install furnace covers (see furnace cover discussion)

5. Other miscellaneous changes that can be accomplished to improve furnace efficiencies.

   - Reduce flue openings to a minimum, the correct design is 20-30,000 BTU per square inch
   - Optimize burner equipment maintenance
   - Maintain clean blower filters
   - Keep flues and slag hole clear

HEAT TREAT FURNACES

Heat treating is the second most energy intensive operation in many foundries. A comprehensive energy management program is mandatory as gas and oil costs continue to grow and diminish in supply. (Some foundries perform no heat treating.)

It is safe to say that many heat treat facilities in the foundry industry are not in particularly good operating shape. Minimum attention is paid to combustion efficiency and refractory maintenance.

Upgrading heat treat furnaces in the following areas will yield tremendous fuel savings:

- Replace existing burners with a modern pre-mix burner system
- Install efficient burner controls
- Install furnace pressure controls
- Replace conventional refractory lining with fiber insulation
- Seal all cracks and openings in casing and doors
- Install combustion air pre-heat system

Each of the above categories is related and dependent upon the state of the others, but will show an energy savings when individual improvements are made. Energy savings can be considered additive when an all out improvement program is implemented.

Process Operation and Control

Heat treat operations fall into two major categories - continuous and batch type. Ignoring specific casting requirements, restricting one process over the other, the continuous operation is favored from an energy conservation standpoint. With continuous operation, the furnace remains at equilibrium and is not heated and cooled and reheated with every new batch processed. The heat required to bring refractory up to various furnace temperatures and the heat lost through the furnace walls to the surrounding ambient temperature, based on varying thicknesses of refractory, is illustrated:

TABLE 2-II HEAT STORAGE AND LOSSES BTU SQ. FT.

WALL THICKNESS	TYPE REFRACTORY	HOT FACE TEMPERATURE °F					
		1,200		1,600		2,000	
		H. ST.	H.L.	H. ST.	H.L.	H.ST.	H.L.
9"	Composite 2,000° insulation and firebrick	13,700	285	19,200	437	24,800	615
13-1/2"	Composite 2,000° insulation and firebrick	22,300	335	31,400	514	40,600	718
22-1/2"	Composite 2,000° insulation and firebrick	43,200	182	61,000	281	79,200	392
6"	Ceramic fiber	842	208	1,170	432	1,490	672

Condensed from mark's handbook
H.ST --- Amount of heat stored
H.L. --- Amount of heat lost (Btu/Sq Ft)

The following information on present operating characteristics is necessary in order to evaluate present furnace efficiencies:

- Fuel flow rate in cubic feet per hour (gas) and gallons per hour (oil).
- Gas or oil usage (by metering) per operating day or week (preferably from fire-up to shut down).
- Casting through-put in tons per hour for the same period.
- Fuel cost in dollars per million BTU's.
- Operating cycle, hours per load, and casting load in tons.
- Furnace operating temperature, waste flue gas temperature, and outside shell temperature.
- Types of existing burners, ratings, and percent of excess air (determined by flue gas analysis).

The above information can be used to determine existing heat input in BTU's per pound of castings processed and, calculate the anticipated heat input after replacement or renovation of existing furnaces. Such calculations form the basis of return on investment calculations that will permit a decision based on economical justification.

LADLE HEATING

The third largest gas consuming process in the foundry industry is ladle preheating. Most foundries use open ladles with Torch Type Gas Burners. Upgrading present ladle heating methods utilizing the following recommended procedures will result in substantial gas energy savings:

- Change unregulated Torch Type Burners to gas/compressed air type regulators.
- Install insulated covers.
- Add insulating lining between conventional refractory and shell.

Ladles come in numerous sizes and shapes, lined with castable or brick refractory or a combination of both. They are first heated slowly to expel moisture, without damaging refractory, until they are dry, then the heating rate is increased to allow refractory surface temperature to reach 2,000o to 2,400° F, primarily to reduce thermal shock to the lining and reduce temperature losses of the metal during pouring. Ladle practices vary largely from one cast metal facility to another. The practice is always energy intensive and what used to be good practice of a well operated shop, to have clean-heated ladles on standby at all times, is poor practice from the standpoint of energy management. The situation of high energy losses becomes progressively more serious when foundries use ancient, dilapidated, or homemade gas torches versus the latest state-of-the-art combustion equipment.

Ladle heating Equipment may be oil or gas fired or a combination of both; electric ladle heating is discussed under "Major Process Changes". See Section H Part 2.

Generally, more efficient heating and drying systems and practices are possible in shops using large ladles where fixed ladle heating stations with covers or hotwalls with fully piped burners are being used. The following diagrams show examples of fixed and wall type ladle stations.

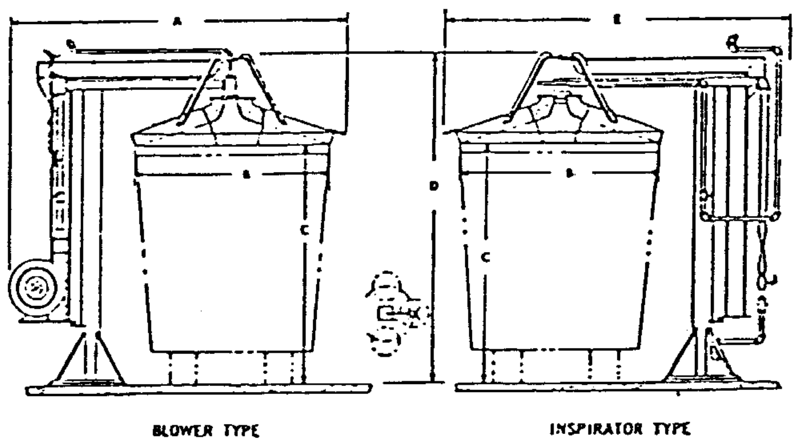


FIGURE 2-11 FIXED TYPE LADLE HEATING STATION

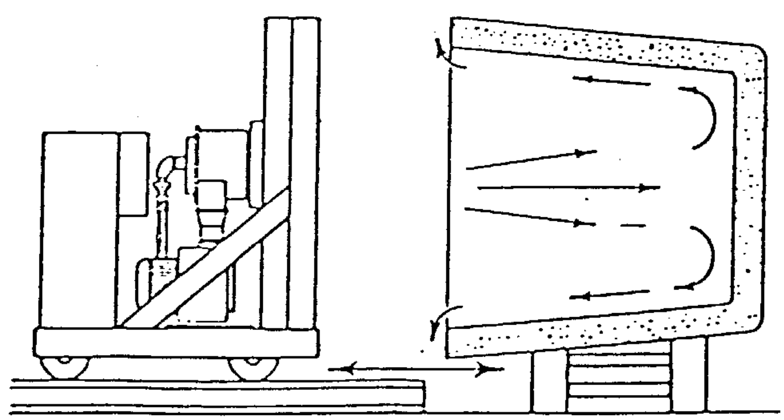


FIGURE 2-12 WALL TYPE LADLE HEATING STATION

With many small foundry operations, the logistics and number of ladles handled make it difficult to maintain fixed burner stations using full air/gas controls. Often portable torches are propped up on the ladle rim, gas flow rates are regulated by means of manual ball or gate valves. Gas consumption can be reduced by two thirds if regulated compressed air is added.

A foundry in the midwest installed regulated compressed air in a 500 pound ladle for drying and heating, they now use 220 cu. ft. of natural gas per hour compared with 660 cu. ft. when using open gas torch only.

The other option for smaller foundries is to substitute electric ladle heaters - see Section 2 Part H for further discussion relative to electric versus gas ladle heating.

Potential indirect energy reduction, due to control of metal temperature in the ladle by utilization of insulation and covers is possible due to control of pouring defects from cold metal and reduction in super heat necessary for metal to be available at optimum pouring temperature when tapped from the furnace.

The possibilities of such savings and increased production make it worthwhile to carefully analyze hot metal handling systems and ladle selections, with the aim of eliminating excessive losses of temperature caused by unnecessary transfers of metal, improper distribution schedules, and inadequate ladle insulation.

In some instances, ladle preheating may be eliminated entirely with the use of insulating fiber ladle linings. See Section 2, part H for further discussion.

COKELESS CUPOLA

A new technology that is creating a great deal of interest is the so called "cokeless" cupola. The basic concept of the cokeless cupola is the replacement of coke as the fuel for melting with a gas or oil fired burner. The charge material is supported by a bed of either refractory spheres or broken refractory products such as bricks. This whole mass rests on a water cooled grate. This concept was originally developed by Taft in England, and further commercialized by several German cupola manufacturers. Approximately fourteen installations exist in Europe and Canada, ranging in capacity from 2 to 20 tons/hour.

A number of advantages are claimed over the use of regular cupolas. The use of gas rather than coke eliminates the pick-up of sulfur from the fuel. This is particularly advantageous for the production of ductile iron. Also, the elimination of coke results in less dust and fume that must be collected in order to meet environmental regulations. It is doubtful, however, that pollution control equipment can be completely eliminated as is the case in some of the Eastern Bloc countries where the cokeless cupola has been more widely accepted.

Another consideration is the cost of the refractory bed material. The Taft style of cokeless cupola used refractory spheres that may or may not be carbon coated to provide carbon to the melt. These are gradually consumed (dissolved) during the operation and represent a significant cost item. Recent work published by the natural gas industry estimates the cost at $17.00 per ton of iron produced. Another type of cokeless cupola, developed in West Germany, uses broken brick as the bed material which reduces the cost. However, the carbon must be added in a separate operation which offsets some of the savings.

The problem of most concern is the difficulty in achieving a sufficiently high iron temperature to allow further processing. If the burners are operated at a fuel/air ratio that would result in the required temperatures, the furnace atmosphere becomes excessively oxidizing which results in iron quality problems. The usual approach is to use a channel induction holding furnace for temperature adjustment and maintenance.

A pilot sized cokeless cupola was built and operated a number of years ago under the sponsorship of the Gas Research Institute. Work on this unit was discontinued and the results not reported to the industry.

The cokeless cupola has considerable potential for the iron foundry, particularly when used in conjunction with a channel induction holder. Further technical and economic evaluations are necessary before the cokeless cupola finds its proper place in the list of options available to the foundryman.

C. COKE AND SUPPLEMENTAL FUELS

USE IN FOUNDRIES

Cupolas are coke-fired counterflow heat exchangers for melting iron. Energy statistics published by the AFS and other organizations show that, on the average, iron foundries using cupolas consume approximately half of their total energy in the cupola. Based on material input to the melting operation, Figure 2-17 and Table 2-III show energy use in the cupola (National Basis) per net ton of good castings.

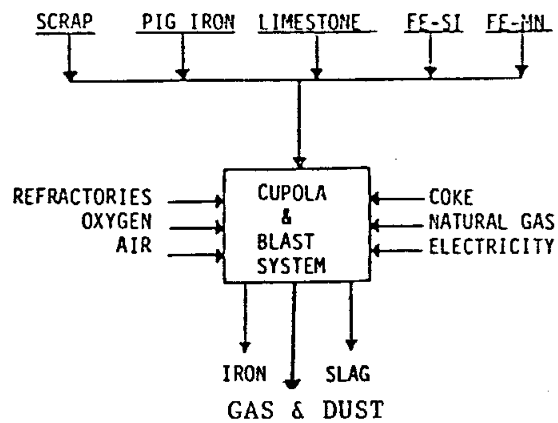


FIGURE 2-13 MATERIALS AND ENERGY USED 1 CUPOLAS

TABLE 2-III ENERGY USE IN CUPOLA (NATIONAL BASIS)

	Million Btu per net ton of good castings shipped(a)
Coke (13% of metallics)(b)	7.76
Transport	0.08
Natural gas	1.60
Electricity(c)	1.05
Scrap	0.00
Transport	0.17
Pig iron	4.17
Transport	0.06
Limestone	0.02
Transport	0.01
FeSi	2.28
Transport	0.01
FeMn	0.75
Transport	0.01
Refractories	0.50
Transport	0.01
Oxygen	0.11
Transport	0.01
TOTAL	18.60

(a) 60% yield from molten iron to good castings shipped.
(b) 33 million Btu/net ton of coke.
(c) 10,500 Btu/kwh.

FOUNDRY COKE

Foundry coke is a solid, cellular residue obtained when certain bituminous coals are heated, out of contact with air, above temperatures at which active thermal decomposition occurs. Coke formed by heating above 1,652° F is called high temperature coke.

Typical foundry coke blends:

TABLE 2-IV. SOME TYPICAL FOUNDRY COKE BLENDS AND COKING CONDITIONS

Plant	Blend, %			Pulv'n[1]	Coking Time[2] in./hr	Flue Temp. Ave. °F	Coke Temp.[3] °F
	Low Vol. Coals	High Vol. Coals	Inert[4]				
A	30.5	56.5	13	80	1.1	2,500	1,800
B	34	60	6	85	0.7	2,200	1,860
C	32	59	9	80	1.1	2,610	1,800
D	50	50	0	88	0.65	1,800	1,750
E	38	56	6	90	1.1	2,300	--

1 Percentage passing 1/8-in screen.
2 Oven width in inches divided by coking time in hours.
3 Average coke temperature calculated from hydrogen content (see "Chemical Tests" in this chapter).
4 Selected anthracite fines meeting foundry coke size and gravity specifications[15].

SUPPLEMENTARY FUELS

Anthracite coal is a dense, hard, natural product ranging in fixed carbon content from 85-87% compared to 90-93% for coke.

TABLE 2-V. MAJOR MATERIAL PROPERTIES

	Anthracite	Coke
Ash	8 - 10%	6 - 8%
Volatiles	4.5 - 5.5%	0.4 - 0.7%
Sulfur	0.4 - 0.65%	0.60 - 0.70%
Heat content (Btu/lb)	13,000 - 13,900	12,500 - 13,500
Material density lbs/ft^3	53 - 58	26 - 32

The greater density gives more energy per volume of space occupied by the coal in the cupola; however, the nonporous nature causes slower burning.

Usage of anthracite coal up to 25% of the total fuel has been reported with some modification necessary to cupola operation and careful control of material size.

If oxygen enrichment is also available, the use of greater than 25% coal may be feasible.

STORAGE

It is common practice at many foundries to store coke in the open. No appreciable deterioration results in mild weather, but when exposed to alternate freezing and thawing, the size can be degraded due to water freezing in the coke fissures. Also, moisture content of coke increases if not stored under cover resulting in increased energy usage to dry the coke charged in the cupola.

OTHER FUELS

Supplementary cupola charge fuels are in use. Coke breeze is used as briquettes or direct injection through the tuyeres.

Table 2-VI shows typical analysis and sizing of the injection grade coke fines being used in a typical injection system. The substitution of injected coke fines for charge coke has resulted in reduction of charge coke by as much as 20%. Replacement ratios of coke removed versus fines injected range from 1:1 and 1.5:1, that is to say, more coke is removed than fines injected with the corresponding cost reduction for materials.

TABLE 2-VI. COKE FINES SPECIFICATIONS

SIZING:	10 MESH X 0	
PROXIMATE ANALYSIS:	Fixed Carbon	88.0%
	Ash	11.0%
	Volatile	1.0%
	Sulfur	0.60%
	Moisture	-1.0%

TABLE 2-VII. COKE SUBSTITUTION VALUES FOR THREE CUPOLA OPERATIONS USING COKE FINES TUYERE INJECTION

CUPOLA	CUPOLA DIAMETER	BLAST TEMP °F	OXYGEN ENRICHMENT	SCFM BLAST RATE X 1,000	MELT RATE TONS/HOUR	% COKE CHARGED	% SUBSTITUTION OF CHARGED COKE	SUBSTITUTION RATIO POUND(S) OF COKE REMOVED TO EACH POUND OF COKE FINES INJECTED	
A	122"	1,200	2%	25-27	50-60	12%	13%	1.3	1
B	108"	950	INTERMITTENT	18	35	15.8%	11.4%	1.6	1
C	46	NO	YES		10	19.5%	10.3%	1.25	1

CUPOLA MODIFICATIONS

Hot Blast and Divided Blast Cupolas. The application of the preheated air blast (hot blast) has improved the combustion efficiency and flexibility of cupola operations. Engineering developments have produced gas fired external heater systems capable of 1000-1200^{o} F blast. Most modern installations incorporate recuperative heating into the design in order to utilize the combustion potential of the off-gas. The hot blast accelerates the combustion reactions and can increase temperature and carbon pick-up thus permitting the use of a higher percentage of steel scrap in the charge, or it can increase melt rate with a lower coke consumption.

Divided blast cupolas utilize a second row of tuyeres to proportionally distribute the combustion air between two levels to obtain increased combustion efficiency and reduced coke consumption.

Oxygen Enrichment

The use of oxygen for cupola melting has been successful on both a continuous and intermittent basis. The amount of oxygen added is usually from 1 to 4%. The application of oxygen enrichment results in increased melt rate, higher temperature and increased flexibility.

D. WASTE HEAT RECOVERY SYSTEMS

GENERAL CONSIDERATIONS

The first step in heat recovery analysis is to survey the foundry and take readings of all recoverable energy that is being discharged to atmosphere. The survey should include analysis of the following conditions:

- Exhaust stack temperatures
- Flow rates through equipment
- Particulates, corrosives of condensible vapors in the air stream

Ventilation, process exhaust and combustion equipment exhausts are the major sources of recoverable energy.

Table 2-VIII illustrates typical energy savings achieved by preheating combustion air with hot exhaust gases from process or furnaces.

TABLE 2-VIII. FUEL SAVINGS REALIZED BY PREHEATING COMBUSTION AIR*

Furnace outlet temperature, F	Fuel savings, percent, when combustion air preheat temperature, F, is: 400	500	600	700	800	900	1000	1100	1200	1300	1400
2600	22	26	30	34	37	40	43	46	48	50	52
2500	20	24	28	32	35	38	41	43	45	48	50
2400	18	22	26	30	33	36	38	41	43	45	47
2300	17	21	24	28	31	34	36	39	41	43	45
2200	16	20	23	26	29	32	34	37	39	41	43
2100	15	18	22	25	28	30	33	35	37	39	41
2000	14	17	20	23	26	29	31	33	36	38	40
1900	13	16	19	22	25	27	30	32	34	36	38
1800	13	16	19	21	24	26	29	31	33	35	37
1700	12	15	18	20	23	25	27	30	32	33	35
1600	11	14	17	19	22	24	26	28	30	32	34
1500	11	14	16	19	21	23	25	27	29	31	33
1400	10	13	16	18	20	22	25	27	28	30	--

* Natural gas with 10 percent excess air; other charts are available for different fuels and various amounts of excess air.

Regardless of the amount or temperature of the energy discharged, recovery is impractical unless the heat can be effectively used elsewhere in the foundry. Also, the recovered heat must be available when it is needed; if not, some sort of heat storage equipment is necessary which will increase the capital cost expenditure and minimize the return on investment.

Waste heat recovery can be adapted to several applications:

- Space heating
- Make-up air heating
- Water heating
- Process heating
- Combustion air preheating
- Boiler feed water heating
- Process cooling or absorption air conditioning
- Charge preheat
- Scrap preheating

An overview of the various heat recovery available will be presented which will cover:

- Air to air heat exchangers
- Air to liquid heat exchangers
- Liquid to liquid heat exchangers

TYPES OF HEAT RECOVERY EQUIPMENT

Choosing the type of heat recovery device for a particular application depends on a number of factors. For example air-to-air equipment is the most practical choice if the point of recovery and use are close coupled. Air-to-liquid equipment is the logical choice if longer distances are involved.

This study addresses five types of heat recovery equipment:

- Economizers
- Heat pipes
- Shell and tube heat exchangers
- Regenerative units

- Recuperators

Economizers

Economizers are air-to-liquid exchangers. Their primary application is to preheat boiler feed water. They may also be used to heat process or domestic water, or to provide hot liquids for space heating or make-up air heating equipment.

The basic operation is as follows: Sensible heat is transferred from the flue gases to the deaerated feed water, as the liquid flows through a series of tubes in the economizer, which is located in the exhaust stack.

Most economizers have finned tube heat exchanges constructed of stainless steel while the inlet and outlet ducts are carbon steel lined with suitable insulation. Maximum recommended waste gas temperatures for standard units is 1,800° F.

According to economizer manufacturers, fuel consumption is reduced approximately 1% for each 40° F reduction in flue gas temperature. The higher the flue gas temperature the greater potential for energy savings.

Heat Pipes

The heat pipe thermal recovery unit is a counter flow air-to-air heat exchanger. (See Figure 2-14)

Hot air is passed through one side of the heat exchanger and cold air is passed through the other side in the opposite direction.

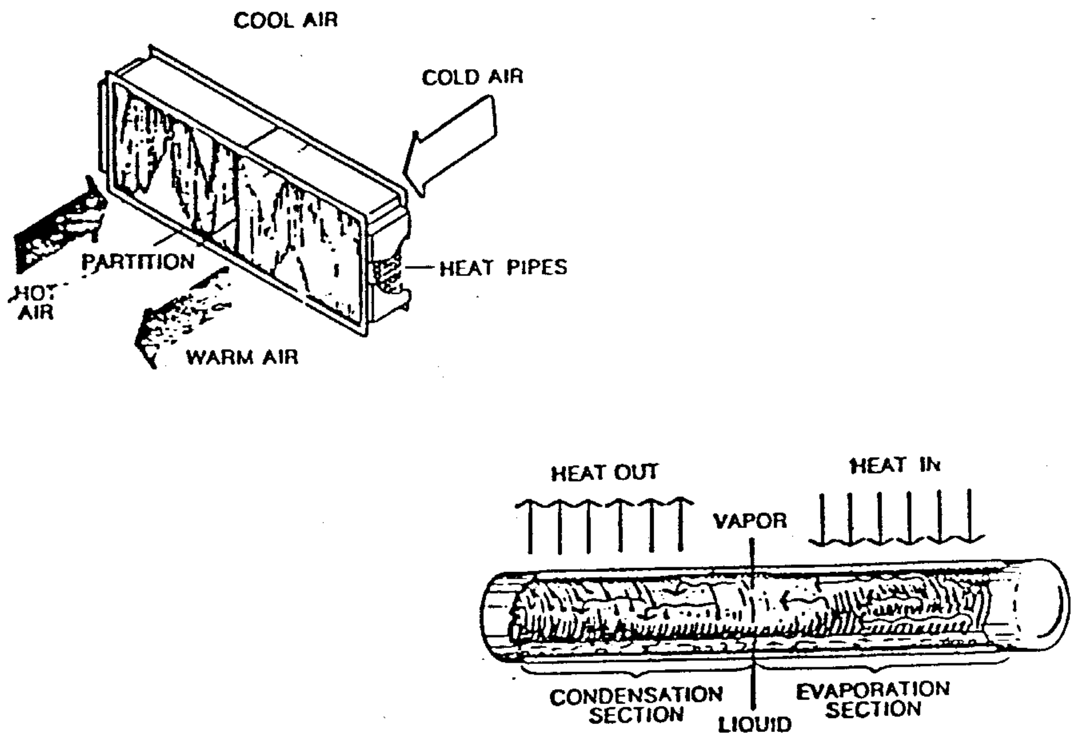


FIGURE 2-14. TYPICAL HEAT PIPE CONFIGURATION

Heat pipes are usually applied to process equipment in which discharge temperatures are between 150° and 850° F. There are three general classes of application for heat pipes:

(a) Recycling heat from a process back into a process (process-to-process)

(b) Recycling heat from a process for comfort and make-up air heating (process-to-comfort)

(c) Conditioning make-up air to a building (comfort-to-comfort)

Heat pipes recover between 60 to 80% of the sensible heat between the two air streams. A wide range of sizes are available, capable of handling 500 to 20,000 cu ft of air per minute. The main advantages of the heat pipe are:

- No cross contamination
- Operates without external power
- Operates without moving parts
- Occupies a minimum of space

Shell and Tube Heat Exchangers

Shell and tube heat exchangers are liquid-to-liquid heat transfer devices. Their primary application is to preheat domestic water for toilets and showers or to provide heated water for space heating or process purposes.

The shell and tube heat exchanger is usually applied to a furnace process cooling water system, and is capable of producing hot water approaching 5° to 10° F of the water temperature off the furnace.

To determine the heat transfer capacity of the heat exchanger the following conditions of the operation must be known:

- The amount of water to be heated in gallons per hour
- The amount of hot process water available in gallons per hour
- Inlet water temperature and final water temperature desired
- Inlet process water temperature

Regenerative Unit (Heat wheel)

The heat wheel is a rotary air-to-air energy exchanger which is installed between the exhaust and supply air duct work in a make-up or air heating system. It recovers 70 to 90% of the total heat from the exhaust air stream.

Glass fiber ceramic heat recovery wheels can be utilized for preheating combustion air with exhaust flue gases as high as $2{,}000^\circ$ F.

Heat wheels consist of: rotating wheel, drive mechanism, partitions, frames, air seals and purge section. Regeneration is continuous as energy is picked up by the wheel in the hot section, stored and transferred to the colder air in the supply section as the wheel rotates through it.

<u>Recuperators</u>

Recuperators are air-to-air heat exchangers built to provide efficient transfer of heat from hot exhaust gases to a cooler air stream.

Recuperators are generally used in the following processes:

- Preheating combustion air
- Preheating scrap metal
- Provide hot blast at cupola's
- Recovery heat from hot gas to supplement or replace the primary heat source in process or comfort heating applications.

There are many different types of recuperator designs available today. The recuperator illustrated in Figure 2-15 is primarily used for combustion air preheating. It consists of three basic cylinders, the hot gases flow up through the inner cylinder, cold combustion air enters at the bottom of the outer cylinder, flows upward and down through the middle cylinder, exiting from the bottom of the middle cylinder.

Heat energy from exhaust gases is transferred through the inner cylinder wall to the combustion air by a combination of conduction and radiation heat transfer. The net effect is preheated air temperatures as high as 1,000° F with inlet exhaust gases entering at 2,000° F and exiting at 1,300° F.

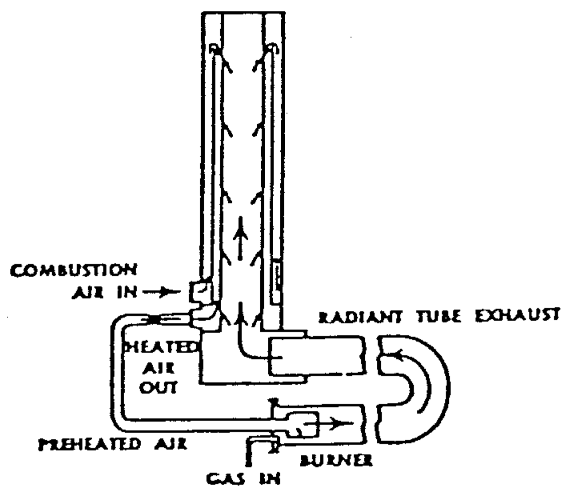


FIGURE 2-15. OPERATING PRINCIPLE OF RECUPERATOR

E. PROCESSES OF SECONDARY IMPORTANCE

As previously stated, approximately 20% of the plants energy input is consumed in secondary processes - no attempt has been made to quantify energy savings in these areas except where actual percentages can be quoted from other sources.

CLEANING AND FINISHING

Material handling, welding, grinding, inspection, and painting processes comprise the minor energy using activities remaining after heat treatment. Areas where additional energy can be conserved:

1. Compressed air tools and hoists require frequent servicing to maintain efficiency. Adequate lubrication is essential to reduce friction in high velocity air motors.

2. Air hoses should be sized for minimum pressure drop to air tools, a 10% drop from designed supply air pressure of 90 psi results in 15% reduction in production output.

3. Replace air driven equipment with induction motors where practical. A high speed induction motor can produce 5 cfm at 100 psi pressure; an equivalent vane type air motor would consume 25 cfm at the same pressure requirement.

4. Check and replace worn sand blast air nozzles to reduce air consumption. 5/16" nozzle worn to 3/8" diameter will consume an additional 55 to 70 cfm.

5. Welding units of the motor generator type should be shut down when not in use. Smoke detector activated exhaust fans over welding area will reduce unnecessary loss of in-plant heated air and power consumption. When using coated electrode-metal arc welding, use the largest diameter electrode possible to improve efficiency.

EXAMPLE

Rod size	Current	kW	Deposition	Welded Efficiency
1/8"	110a.	5.6	0.87#/hr.	47%
3/16"	150a.	7.65	1.32#/hr.	51%
1/4"	250a.	13.65	2.50#/hr.	55%

6. Paint lines should use airless spray guns. It requires 9.5 HP to atomize 1 gpm using air spray, compared to approximately 1.3 HP for airless type.

7. Consider direct fired paint drying ovens instead of indirect. The heat transfer coefficient for direct fired is about 97% vs. 60% for indirect.

8. Install insulation on paint line heated wash and pretreatment tanks. For instance, an uninsulated vessel at 200° can waste up to 315 BTU/hr/sq. ft. Investigate using recovered process heat as source for paint line heating requirements. Schedule paint line for continuous period of operating rather than frequent shut downs and start ups. Robot painting manipulators can be programmed to start and stop the cycle as required.

9. Fork truck idling time and use of oversize vehicle for job wastes energy. Install door opening and closing devices operable by truck driver in the operating seat. If possible, install double air-lock doors. In large facilities use portable radios to direct fork trucks to next assigned area to reduce empty trips.

10. Improve work flow to reduce handling and movement.

MOLD AND CORE MAKING

The following modifications, changes, and additions to mold and core making operations to effect energy savings are:

1. Install manual shut-off valves on each gas distributing line on shell core making machines.

   Example: A foundry in the midwest installed valves to control the flow of gas to each row of burner tips. Their objective was to use only as many gas tips as were required to heat the core box. By cutting off one row of burner tips, their energy savings amounts to 256 x 10^6 Btu per year.

2. Convert from hot box phenolic resin cores to cold box cores.

   The same foundry as in (1) above saved gas in the amount of 1.170 Btu per pound of core or 675 x 10^6 Btu per year. In addition, they produced the cold box cores about three times as fast as the bottom box cores.

POURING AND SHAKEOUT

The following modifications, changes and additions to pouring and shakeout operations to effect energy savings are:

1. Excessive lighting levels over areas of mold cooling and incandescent lights used at work stations can be changed to reduce energy. Reported improvements of up to 15% were obtained by switching to high-pressure sodium lighting at a New Haven foundry.

2. Movement of clean waste heat to where it is needed can be profitable by recovery of heat from molds and cooling areas for process heat in other areas.

3. Pouring yield, that is, the effective weight of castings per mold relative to gross metal poured into the mold, is an important statistic indicating efficiency of pattern layout and gating techniques.

   An improvement in pouring yield from 40% to 45% reduced energy in remelting the returns approximately 9% at Hayes Albion and even at 60% yield, about 40% of melt energy is still being dissipated by recycling of metal within the foundry. Yield improvement will be discussed further in Section 2, Part G.

4. Shakeout systems operating with no load and excessive sand to metal ratios consume energy with no increase in production.

COMPRESSED AIR SYSTEMS

A number of simple guidelines, if effectively followed, can save foundries significant amounts of energy through conservation of compressed air.

Conservation measures are especially needed to increase the efficiency of pneumatic cylinders. Some foundries have oversized cylinders and longer than necessary strokes. Only one cylinder size is correct for any given application and knowledgeable suppliers can provide the information necessary to determine the correct cylinder for any specific operation.

Use of higher pressure than those required wastes considerable compressed air; limiting pressures to the desired level with quality regulators quickly repays the initial investment. Figure 2-16 shows effect of different line pressures.

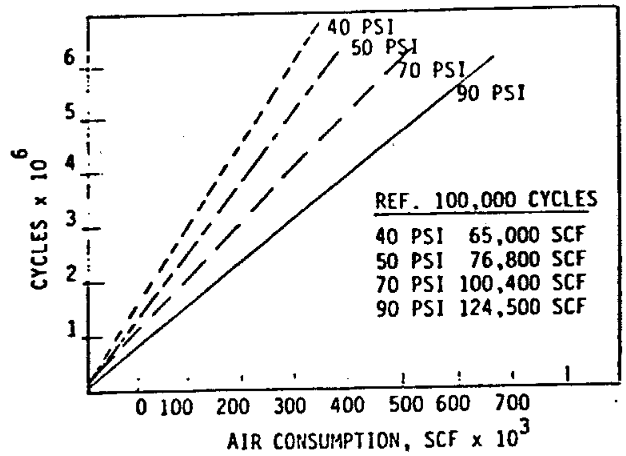


FIGURE 2-16. HOW LINE PRESSURE AFFECTS AIR CONSUMPTION

A large percent of cylinder and rotary actuator applications require maximum thrust in one direction only and the return stoke can be made with greatly reduced pressure — this is true with jolting, squeezing, stamping, swaging, clamping, and cutting operations — see Figure 2-17.

WITHOUT REGULATOR	
Advance stroke	90 psi
Retract stroke	90 psi
Air consumed	156 cu.in./cycle
WITH REGULATOR	
Advance stroke	90 psi
Retract stroke	20 psi
Air consumed	112 cu.in./cycle
Air saved	28%

FIGURE 2-17. HOW PRESSURE REGULATION SAVES ENERGY

Air Leaks

Leaks occur from defective hoses, couplings, fittings, valves, tubes, and actuators. Even leaks that cannot be detected audibly contribute to substantial energy losses. The cost of energy loss through misapplication and leakage in pneumatic systems is so appreciable that it often results in foundries purchasing unnecessary air compressor capacity. Unnecessary expenditures combined with wasted air can be curbed with effective energy management.

Example of loss in energy due to leaks:

- 1/16 inch diameter air leak uses about 2,520 kwh/year
- 1/8 inch diameter air leak uses about 10,100 kwh/year

DUST AND FUME COLLECTION

Dust collection equipment (baghouses, scrubbers, etc.) and its associated exhaust fans and miscellaneous accessories consume relatively large amounts of electricity.

Foundries generate a lot of dust and fumes in many phases of production. In order to satisfy the Environmental Protection Agency (EPA) and local air pollution control agencies, large volumes of air need to be exhausted. Often, exhaust air must be replaced with pre-heated make-up air, adding to overall energy consumption.

The energy savings potential for dust of fume collection equipment is minimal providing the system is operated and maintained correctly. The following checklist should be implemented to minimize electrical power consumption.

1. Install well designed ventilation hoods to keep air volume to a minimum.

2. Keep pressure drops across filters within initial design parameters.

3. Develop and maintain strict preventative maintenance procedures. (Check for leaks and infiltration.)

4. Turn system off when not needed.

Recent work indicates that the use of Adjustable Speed Drives (ASD) can provide significant energy savings over motors operated at constant speed.

HEATING, VENTILATION, AND AIR CONDITIONING

The need for comfort heating, ventilation and air conditioning can be significant in some areas for offices, pattern shops, laboratories, and the like.

Investment casting facilities generally have fairly large process air conditioning systems with stringent humidity requirements. Interior design conditions are usually 72° F dry bulb temperature and 45° relative humidity which requires both summer dehumidification and winter humidification.

Due to the many types of system variations and equipment applications in investment casting facilities it is impossible, and beyond the scope of this study, to recommend energy conservation measures in specific terms. Facilities with air conditioning systems larger than 20 tons (240,000 Btu/hr) should engage qualified professionals to optimize system performance.

The following list points out some areas where energy could be conserved either by retrofit, changes and/or modifications to existing systems:

- Add additional insulation to roofs, ceilings, or walls where practical.
- Install solar film on windows to cut cooling loads.
- Install weather stripping around windows and doors.
- Install higher efficiency lighting systems where possible.
- Recalibrate all controls.
- Lock thermostat to prevent resetting by unauthorized personnel.
- Install enthalpy controls to optimize use of outside air for natural cooling.
- Retest, balance and adjust systems.
- Turn off air conditioning machinery during unoccupied hours.
- Optimize system startup times.
- Reduce outdoor air and system air volumes.
- Replace forced air heaters with infrared heaters.
- Insulate piping and ductwork in unconditioned spaces.
- Reclaim process exhaust energy and utilize it for space heating and absorption cooling.
- Install solar-assisted heat pumps.
- Replace constant volume air systems with variable volume type.
- Use proper water treatment to reduce fouling of heat transfer surfaces in chillers and heat exchangers.
- Maintain all equipment for peak efficiency.
- Storm doors and windows.

PROCESS WATER

Some foundries utilize "once through" process cooling water systems for melt furnace and quenching operations.

Water recovery in the foundry is a valuable source of increasing operating economics, and can lend itself to energy recycling. Cooling for hydraulic presses, air compressors, melting furnaces, and quenching operations is generally accomplished with water. As much as 98% of otherwise wasted water can be recovered by installing a "closed loop" recirculating water system. The evaporative cooler, commonly referred to as a cooling tower is normally used for this purpose.

PLANT LIGHTING SYSTEMS

Foundries utilizing incandescent lighting systems can save significant amounts of energy by replacing existing units with high pressure sodium units. For example: If a foundry replaced 365 - 1,000 watts incandescent units with 185 - 400 watt high pressure sodium units (HPS) the resulting decrease in electrical load would be 288 kilowatts with no significant change in light level.
Assuming the lights burned 250 days per year, and 8 hours per day and the cost of electricity was 15 cents/kwh, the energy cost savings would amount to:

288 kw x 250 x .15 = $86,400

In addition to conserving electrical energy, further saving can be realized in replacement costs due to the longer life of the HPS System.

PART F

LONG TERM PROCESS CHANGES

CHARGE PREHEATING

Preheating of charge material is considered to be cost-effective, however, total use of energy may increase.

Overall energy reduction would be possible with gas preheating provided that waste heat is recovered for combustion air heating.

The percent heat distribution in melting iron from 70° F temperature to 2,700° F is as follows:

Form	Temperature	Sp. heat Btu/lb./°F	Heat Content Btu/lb.	Percent Heat Required	Stage
Solid	70° F	0.130	10		
Solid	1,000° F	0.140	140	65%	Preheat
Solid	1,200° F	0.147	176		
Solid	2,300° F	0.161	370	22%	Melt
Liquid	2,300° F	0.214	492		
Liquid	2,600° F	0.209	543	13%	Superheat
Liquid	2,700° F	0.208	562		
				100%	

FIGURE 2-18. THERMAL PROPERTIES OF IRON

The percent heat required column indicates that major energy is used to preheat the metal.

The methodology used for comparing gas preheating versus all electric melting is as follows:

Heat required for preheating is expressed as

Btu/lbs. of metal = $(t_1 - t_2)$ x specific heat

Where :

t_1 = final preheat temperature (1,000° F)

t_2 = initial cold temperature (70° F)

Specific heat of iron (0.140)

Therefore: Heat required to raise to 1,000° F is:

(1,000 - 70) x 0.140 = <u>135.8 Btu/lb.</u>

COGENERATION

Cogeneration, in simplistic terms, in a process of "energy cascading" by utilization of waste heat from various foundry operations (i.e., heat treat furnaces, melt furnaces, etc.).

The first step (or top cycle) of a cogeneration system is the generation of electricity which is used for in-plant electrical base load or peaking load service. The electricity produced replaces, in part, that which is normally purchased from the utility company. The last step (bottom cycle) in the thermodynamic cycle is the use of waste steam for industrial processes and/or environmental conditioning (see Figure 2-19 below).

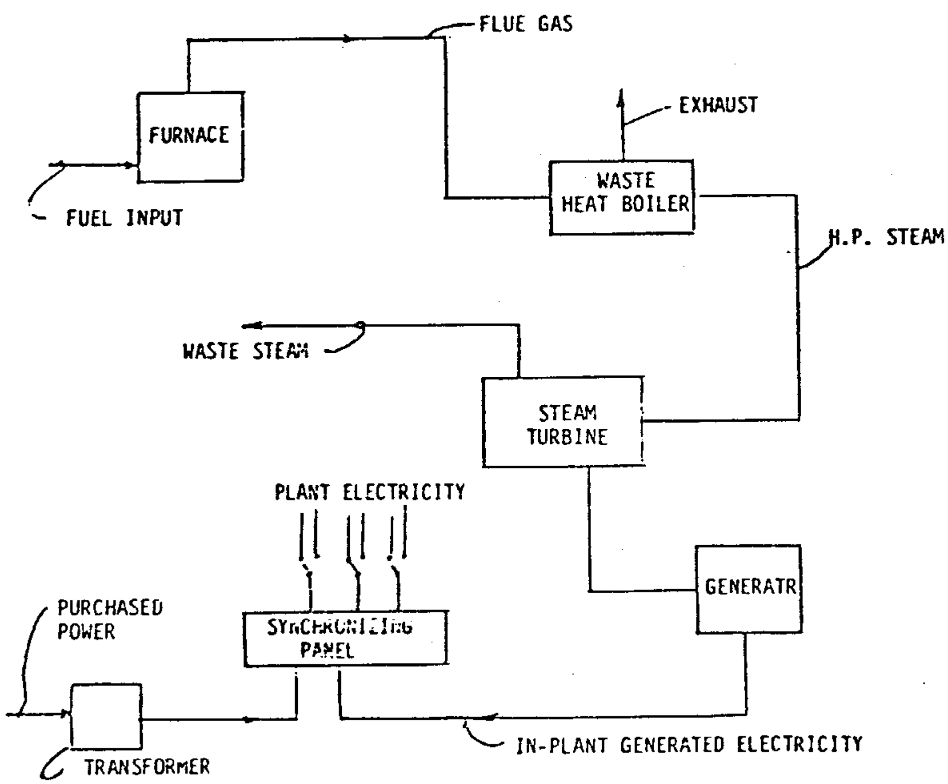


FIGURE 2-19. COGENERATION BLOCK DIAGRAM

Cogeneration in a typical foundry is an intermittent operation, electricity production is possible only when equipment that is developing waste heat is operational.

Referring to cogeneration block diagram, Figure 2-19, the following major equipment is required for on-site power generation:

- Waste heat recovery boiler; these are available in water tube or fire tube design.
- Steam turbine
- Electrical generator
- Automatic synchronization equipment

Generation of on-site power by utilization of plant waste heat is extremely costly to install and maintain. Also, generation of high pressure steam could possibly require a full-time Class "A" boiler operator.

The complexity and initial expense of cogeneration, when applied to the typical foundry, is not cost-effective at this time. A detailed and comprehensive analysis would be required to justify the use of on-site power generation in a foundry of suitable size to warrant such a system.

PART G

MANAGEMENT ACTIONS

YIELD IMPROVEMENT PROGRAMS

Improvement in mold yield, to increase good castings relative to total poured metal, has a direct impact on energy usage by reduction of total melted metal required for a fixed weight of good castings.

Yield is made up of several parts comprising the effects of:

- Melt loss due to oxidation
- Slag
- Spill metal
- Pigged metal
- Pouring system, (gating, risers, excess casting weight)
- Scrap losses, grinding and machining losses

The typical foundry overall yield is 50% which results in required energy to melt double the finished casting weight. One percent yield improvement for 100-pound casting, from 50% to 51%, reduces metal melted by 4 pounds. (Yield varies with metal melted and processes used.)

Melt Losses:	Occur in all melting processes and range from 1-2% in electric furnaces to 7-10% in cupolas or higher in direct gas-fired furnaces. Selection of raw materials and redesign of melting unit and method changes can minimize the loss.
Slag:	Generated from impurities in the metal and oxidation, includes a percentage of pure metal, operating practices to restrict excess metal entrapment in the slag are necessary.
Spill:	Inaccurate pouring and poor transfer techniques result in metal melted that is not available for casting.
Pigged Metal:	Can amount to 1-2% of total metal melted. The correct measurement of ladle quantities is necessary in order to avoid skulls remaining after pouring. Correct sizing of ladles to prevent exceeding the workable pouring temperature range, before all the metal is utilized, will reduce pigging losses.

Pouring Systems: Ratio of poured metal to gross castings is the base yield figure. Improvements to runner systems, small risers or exothermic/insulators on the riser are required in an ongoing program to attain good yields.

Lightening of castings, if acceptable by the customer, will also reduce metal melting requirements and total energy used. The change may be in design of casting section thickness or closer tolerance to produce a casting with mold wall movement and "swell". The effect of weight reduction is shown in Figure 2-20.

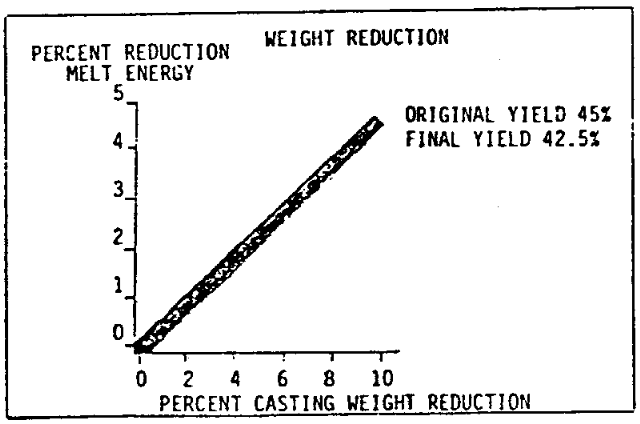


FIGURE 2-20. EFFECT ON MELT ENERGY OF REDUCING CASTING WEIGHT (Hayes Albion)

Scrap: Reduction of scrap is of utmost importance in all foundries for overall cost reduction and energy savings. Figure 2-21 shows the melt energy savings when scrap is reduced from 10 percent to zero. There is an approximately linear relationship of energy reduction to scrap reduction; i.e., one percent scrap reduction saves one percent in energy input.

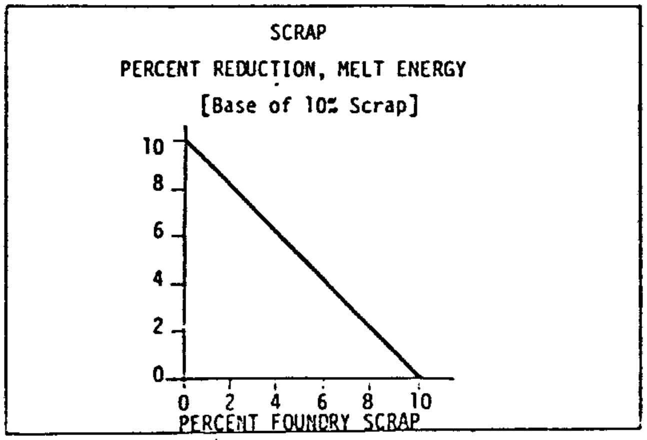


FIGURE 2-21. EFFECT ON MELT ENERGY BY REDUCING SCRAP

COMBINED EXAMPLE

	Sales Weight	Scrap	Yield	Melt Weight	Percent Energy Reduction
BASE	100%	8%	4.5%	241.5%	0
IMPROVE YIELD	100	8	$\boxed{50}$	217.4	8
REDUCE SCRAP	100	$\boxed{6}$	$\boxed{50}$	212.8	1.9
REDUCE SALES WT.	$\boxed{85}$	$\boxed{6}$	$\boxed{50}$	202.1	5.4
					$\boxed{15.3}$

FIGURE 2-22. EXAMPLE OF EFFECT ON MELT ENERGY WITH COMBINED IMPROVEMENTS IN YIELD, SCRAP AND CASTING WEIGHT

Grinding and Machinery: Losses due to machining away parts of the casting and grinding to remove ingate pads etc. must be minimized by design and careful positioning of ingates on the casting. Cooperation between customer's design engineer, on initial casting configuration, and the pattern maker is essential.

ESTABLISH ENERGY MANAGEMENT PROGRAM

For an energy management program to be fully effective foundry management should establish the position of "Director of Energy Conservation". The functions of this office would be:

- Establish the total energy cost per unit for each department or division.
- Perform in-plant inspections to identify energy conservation opportunities.
- Establish and maintain an on-going energy conservation program in each department.
- Establish an in-house training program for department supervisors.
- Analyze future energy requirements.
- Assist in establishing plans and capital investment requirements for implementation of conservation programs.
- Provide personal contact between various utility companies.

A single person cannot physically handle all the above assignments; the Director of Energy Conservation must form a committee comprised of top level management people and other members of virtually all departments of the foundry such as melting, heat treating, mold and pouring, cleaning and finishing, and maintenance. The committee thus formed must coordinate a total energy management program to determine what is to be done to reduce the amount of energy used.

After determination of energy reduction measures the committee must follow through with the modifications and changes, to equipment and processes, necessary to accomplish the end results.

Implementation of a full scale energy management program coupled with comprehensive preventive maintenance procedures will, by refining proven and successful foundry management concepts, derive major energy and cost savings.

Efforts to improve foundry profitability by reducing equipment and process downtime, increasing yield through reducing casting weight, reducing scrap and improved scheduling will also payoff in conservation of energy and related cost savings.

All out efforts to reduce energy consumption will significantly reduce the cost per ton of shipped casting, which will improve sales and profits. These challenges and opportunities are present in all foundries and should be carefully addressed by foundry management.

For a listing of software titles available in the market for energy mangament programs, begin your search at the U.S. Department of Energy-- (202) 586-2090.

OPERATING PROCEDURES

Management approach must be to plan for operating with minimum energy usage. Improved scheduling in terms of when to run partial loads or reduce melting to fewer days but longer hours per day are very basic decisions.

It is not intended that all equipment operate 24 hours per day; careful scheduling can provide for metal to be melted up to pouring temperature at the time it is required, early melting will waste energy due to holding at temperature for long periods.

Changes in processes can be justified in energy savings, for example: shell or hot box core making conversion to cold box or no-bake methods.

General control of heating and high energy using equipment is necessary to see that it is only running when needed. Heat treat furnaces operated on a condensed schedule of several loads back to back will reduce the total energy required to initially heat up the mass of refractory.

Demand limiters for electric power and shifting the production or melting program to take advantage of off-peak power rates is also covered elsewhere.

Advantages of energy efficient conversions from direct fuel fired equipment to electricity may also be considered in terms of quality control refinements, improved operating conditions, with noise and exhaust requirements reduced. In nonferrous melting operations the cost advantage of reduced melt losses with electric melting frequently offsets the added energy cost.

A checklist of practical energy conserving suggestions covering plant operations for management to investigate is included in Section 4.

PART H

MAJOR PROCESS CHANGES

MELTING (GAS VERSUS ELECTRIC)

Foundries engaged in the planning of new melt facilities or contemplating major changes to existing facilities should analyze gas versus electric melting, particularly from the standpoint of fuel availability and price in the future. The following table illustrate the differences in energy consumption for various types of melting practices.

Energy usage by alternate fuels is shown on the following Table 2-X.

TABLE 2-X. ENERGY REQUIREMENTS FOR MELTING AT 100% POWER UTILIZATION

ENERGY CONSUMPTION IN KWH PER TON					
METAL	TEMPERATURE (°F)	HEAT CONTENT KWH/TON	THEORETICAL OIL-FIRED	GAS AND COKE-FIRED	ELECTRIC (****)
Aluminum	1,400	295	1,406*-2,138**	N.U.	500
Copper	2,300	190	1,523*	N.U.	334
Gray Iron	2,750	340	N.U.	801***	500
Steel	3,000	363	N.U.	N.U.	606

References:
*Crucible Handbook, Crucible Institute.
**Stahl Specialty Company (Reverberatory Furnace).
***Cupola Handbook, AFS, 1965, P.292.
****Published Data by Induction and Arc Furnace Companies.

Example: Assume a requirement to operate six 2,000 lbs/hr aluminum melters with overall yearly utilization of 70 percent (no preheat).*

Furnace	Melting Therms Per Ton/Yr	Holding Therms Per Ton/Yr	Therms/Ton Per Year
Gas/Oil Reverb.	304,760	72,489	377,249
Gas/Oil Crucible	288,000	-	288,000
Coreless Induction	101,798	6,231	108,022
Channel Induction	71,744	3,232	74,976
Elect. Reverb.*1	88,965	1,100	90,065

*Note: Above costs should be adjusted for particular situation and user energy rates.

Energy only cost differences shows advantage for channel induction and gas crucibles, however, for cost justification analyses, other factors such as capital cost, maintenance, melt loss due to oxidation and general process variable should be taken into account on an individual basis.

MELTING (COKE VERSUS ELECTRIC)

Coke Fuel for Melting in Cupolas

The most efficient cupola system is a highly utilized large scale, uninterrupted operation. This will present the best metal to coke ratio. Provided that the coke ratio does not change during melting, the only additional coke charges made are to compensate for variations in operation.

The length of campaign will also be reflected in bed coke usage, with ratios as low as 1:1 for short daily melting cycles, also delay in blast-on time, after igniting the coke bed, allows excessive burn-out and waste.

Distribution of energy from cupola coke is shown as follows:

	Percent
Heat in melted iron	40
Latent heat in stack gas	35
Sensible heat in stack gas	13
Other (slag, losses)	12
	100

Modifications to the conventional cupolas to recover much of the stack loss is feasible by use of the recuperative hot blast techniques, but a foundry may decide against this method because of excessive capital costs and tending to plug. Divided blast systems, where the tuyeres are located in two rows, separated by approximately 36 inches, is proven to increase top temperatures and reduce coke. Coke savings is also possible by enrichment of the blast air by 2.0 to 4.0 percent oxygen.

Injection of coke breeze to reduce fuel cost plus use of Anthracite coke and shredded auto tires, as an energy and carbon pick up source, are other methods of savings, however, in all cases the degree of savings is proportional to the capital cost and/or operating problems incurred. These energy reduction methods are all in use, but the total combination of savings is only available under experimental situations. Capital costs of over 1.0 million dollars is reported to be involved in upgrading cupolas for full maximization of energy savings.

Electric Furnace Melting

Furnaces for melting with electric power are available as follows:

- Direct Arc
- Coreless Induction
- Channel Type Induction
- Resistance Type - Reverberatory Furnaces

The efficiency of electric melting is highest where a full bath of metal at liquid stage is being heated. Ability to maintain temperature within close tolerance and melt on a continuous or intermittent basis is of major advantage in electric melting. Other applications of electric power usage, as applied to the melting of metal, is covered elsewhere in this study.

COST COMPARISON COMPUTER ANALYSIS

Computer models have been developed to determine cost comparisons between induction and cupola melting for iron, and between induction, electrical resistance, and gas-fired melting for non-ferrous metals. These models can be accessed through the EPRI Center for Materials Production, Pittsburgh, Pennsylvania; or the CMP Foundry Office, Arlington Heights, Illinois.

LADLE PREHEAT (GAS VERSUS ELECTRIC)

Electric ladle drying and preheating costs can be cut as much as 50%, depending on utility rates, by use of electric silicon carbide globar type elements utilized in conjunction with correctly designed ladle covers and controls.

The high thermal efficiency of electric ladle heaters, as compared to gas combustion devices in which a very large part of the available heat is wastefully vented to atmosphere, will afford maximum energy savings. As an added feature automatic programmed temperature control will provide close temperature control without overheating.

Figure 2-23 shows attainable curing and preheating cycles for 2,000-pound, 30-inch diameter ladle with a 65 kW heater.

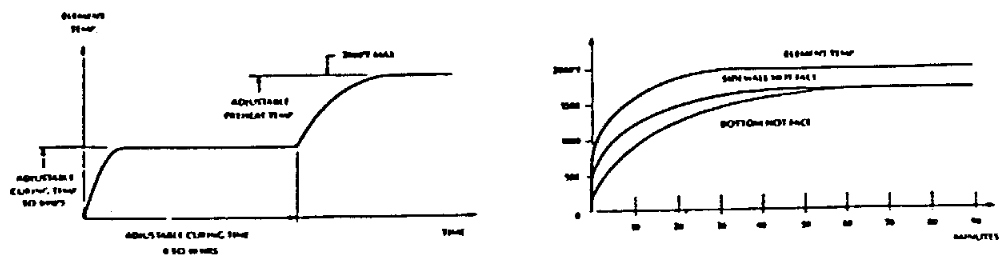


FIGURE 2-23. ELECTRIC LADLE PREHEATER PERFORMANCE (30" DIAMETER LADLE)

Units available to suit ladle sizes are as follows:

kW	Ladle Size	Capacity-Pounds
25	17-1/2 - 21-1/2	500 - 1,000
40	21-1/2 - 27	1,000 - 2,000
65	27 - 34-1/2	2,000 - 4,000
100	34-1/2 - 43-1/2	4,000 - 8,000

Insulating Board Linings

A recent innovation in ladle lining practice is the use of disposal insulating board linings. The boards resemble conventional wall board in consistency, and are produced from either silica or magnetite refractory grains bonded with an organic resin. The boards are supplied as segments that are fitted together to form the walls of a ladle lining, and are backed by a permanent refractory safety lining. The gaps between the boards and the safety are filled with dry sand. A separate board ladle bottom is also often used. These same insulating materials are available in pre-shaped complete linings for small ladles as well.

The main advantage is that these linings do not require preheat and are used as "cold linings". Although the cost of these linings is high, energy savings can often compensate. These linings are designed to be used only once and then replaced in order to insure the highest quality of castings. Use of the boards for more than one heat (fill) causes rapid breakdown of the refractory and results in deterioration of casting quality.

SECTION 3

ANALYSIS OF ENERGY CONSUMPTION

This section provides all necessary charts, graphs, tables, and mathematical formulas for the development of energy savings in quantitative form for:

- Electric power and cost savings relative to the melting of metal in all available types of furnaces. By utilizing hypothetical mathematical models it will be shown how to cut energy cost and/or consumption by improving power factors, installing demand limit controls, changing to "off-peak" melting and demand shifting.

- Gas energy reduction relative to melting, heat treating, and ladle preheating. By utilizing hypothetical mathematical models it will be shown how to reduce energy cost and/or consumption by improving combustion efficiencies, installation of ceramic fiber lining, installation of covers, and adding combustion air preheating.

- Reduction of coke usage in cupola melting by upgrading equipment such as adding hot blast via stack gas recuperation divided blast and oxygen enrichment. Also shown is the comparative energy usage for cupola versus electric melting.

A. ELECTRIC MELTING

GENERAL

As stated previously in Section 1 of this report, approximately 34% of the total energy input (all fuels) to a typical steel foundry is in the form of electricity. Of this 34% approximately 60% is attributed to the melting of metal. This section deals with energy and cost savings in electric melting operations and covers the following areas.

- Furnace operation
- Energy usage
- Demand
- Demand control
- Off-peak melting
- Demand shifting
- Power factor correction

INPUT DATA

The required input data needed to analyze present melting operations, from the standpoint of energy consumption is:

- Electric utility bills for the past twelve months
- Kilowatt demand load profile
- Rate schedule for summer and winter "Time of Day" billing

The kilowatt demand load profile covers a period of 48 hours and represents an electrical demand requirement for electric melting (See Figure 3-1). The load profile was developed from the kilowatt demand printout (See Table 3-II). From Table 3-II, it should be noted that the kilowatt demand for each five-minute interval for each 24-hour period is listed.

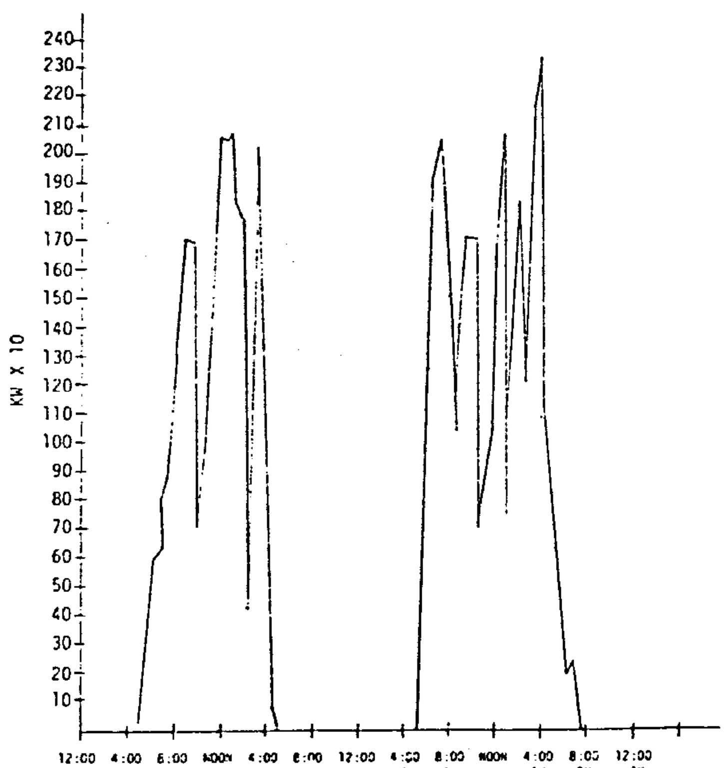
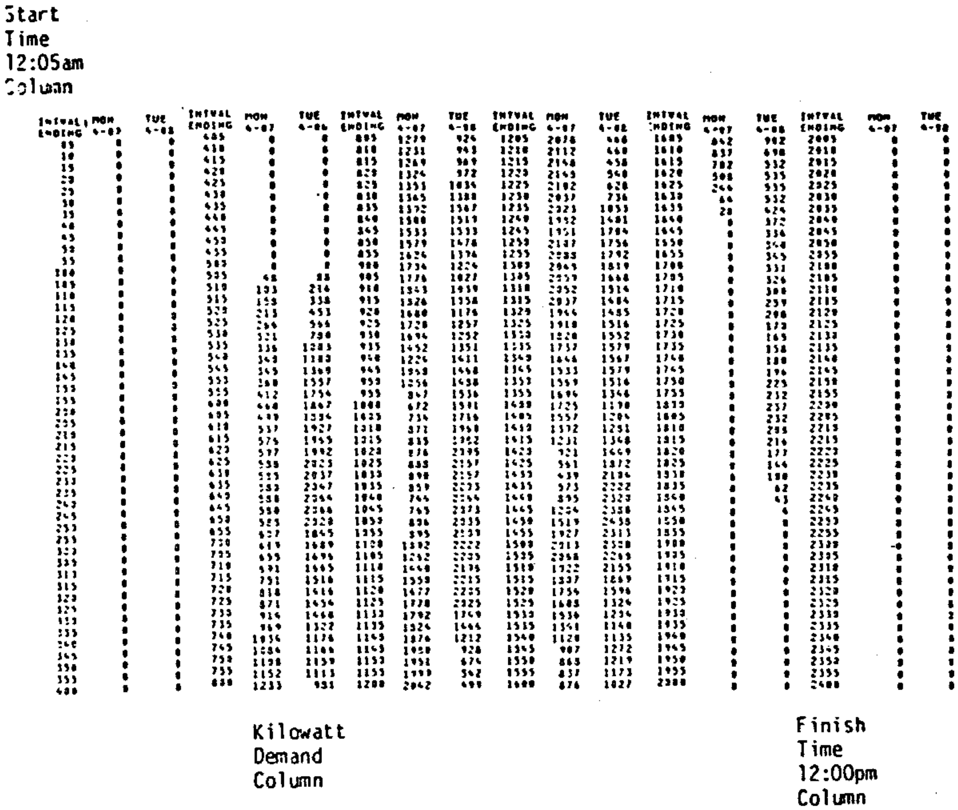


FIGURE 3-1. ELECTRICAL LOAD PROFILES

TABLE 3-II. KILOWATT DEMAND PRINTOUT



LOAD PROFILE DEVELOPMENT

Foundries with a separate electrical service to their melting furnaces can develop their own in-house kilowatt load profile in the following manner. Prepare a chart, using graph paper with one-tenth of an inch/to one inch divisions, recording time along abscissa axis and kilowatt demand along ordinate axis. Along the abscissa axis set out the "time of day" billing hours. Setting up the graph in this manner will indicate if the high kilowatt demands are occurring during the "on peak" hours (See Figure 3-2). From the kilowatt demand printout, record the thirty minute kilowatt demands for chosen time periods. When all 30-minute kilowatt demands have been recorded, connect all points to obtain profile of load. The procedure for developing a winter kilowatt load profile is the same as "summer", but the "time of day" billing hours change (See Figure 3-3).

Foundries that are not provided with a kilowatt demand printout for their electric melting operation or have only one electrical service for both melting and general plant service will need to install submetering of the service feeders.

Using a three-phase tap-type recording ammeter and a clipon type power factor meter the necessary data can be obtained to find the kilowatt demand.

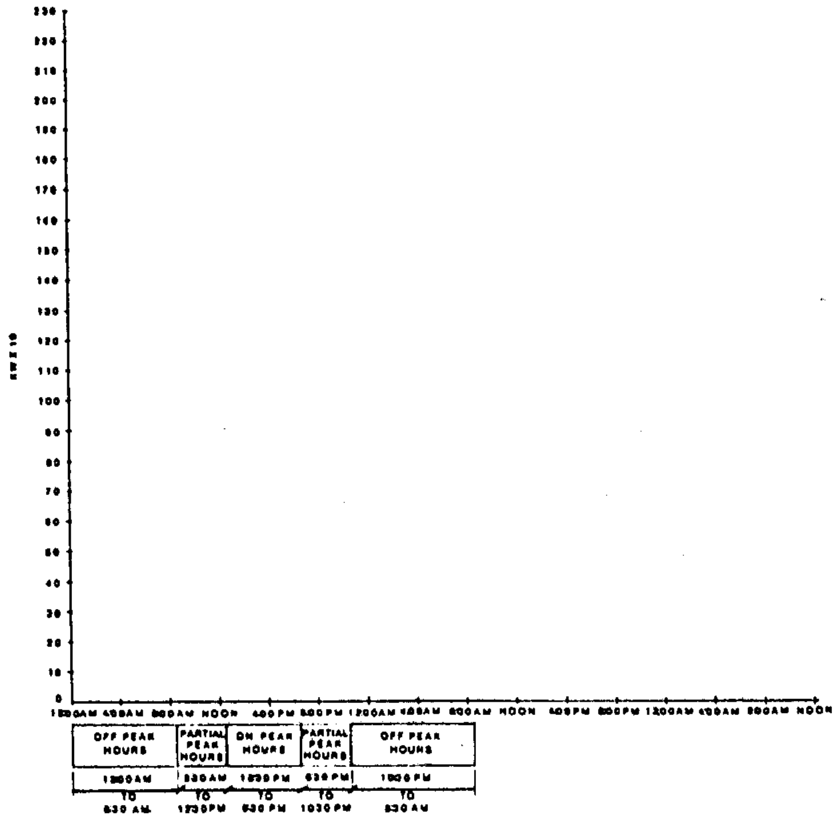
<u>Example</u>

If the ammeter recorded 400 amperes with a 0.80 power factor the kilowatts would be as follows:

$$\frac{I \times E \times 1.73 \times PF}{1000}$$

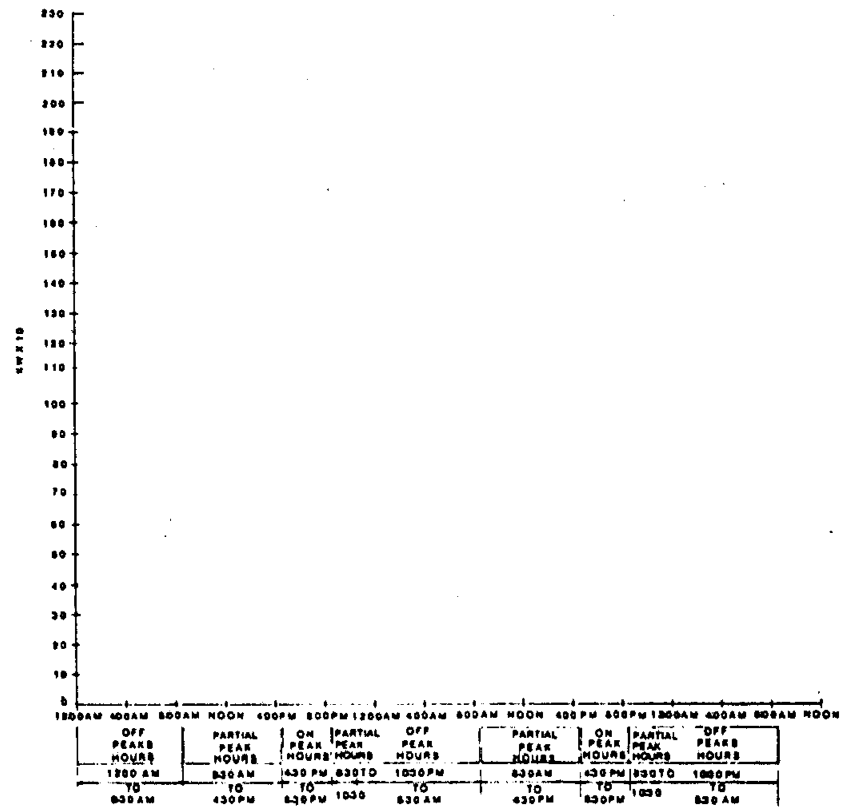
$$\frac{400 \times 480 \times 1.73 \times .80}{1000} = 265 \text{ kilowatts}$$

From the above reading the kilowatt load profile can be developed.



KILOWATT DEMAND PROFILE (SUMMER)

Figure 3-2



KILOWATT DEMAND LOAD PROFILE (WINTER)

Figure 3-3

OFF-PEAK METAL MELTING

By utilizing "off-peak" hours for metal melting, substantial cost savings can be realized through lowering the demand and energy charges.

Figure 3-4 illustrates a total demand load of 2,300 kilowatts, of this amount approximately 59% or 1,357 kW is attributed to melting of metal, the remainder is base plant electrical load.

The following sample calculations illustrate the electrical cost for demand, energy and fuel adjustment charges for melting in on-peak and off-peak hours.

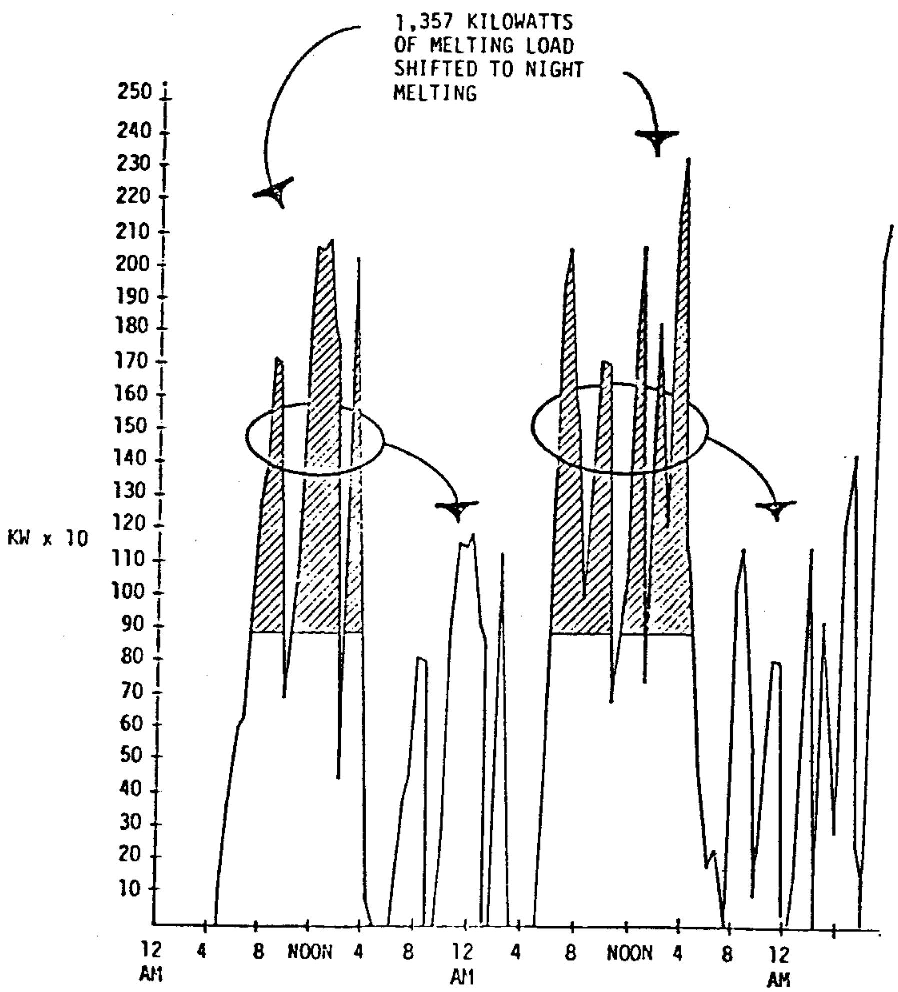


FIGURE 3-4

DEMAND SHIFTING AND DEMAND CONTROL

If night melting is not possible, demand shifting and control will permit metal melting during normal "on-peak" day time hours and still save substantial costs. Demand shifting will extend the melting period; this permits the sequential operation of the furnaces, thereby reducing the peak maximum demand.

With uncontrolled operation, large kilowatt demands are developed which produces low demand factors and low efficiency of power usage. Figure 3-5 is representative of an uncontrolled operation of power input to several furnaces. Figure 3-6, indicates how the kilowatt demand can be reduced by extending the hours of melting operations with the demand limit set at 1,700 kilowatts. The sample calculations illustrate the potential cost savings if demand shifting and control is utilized. To insure complete control of a set maximum demand an automatic demand controller should be installed, this controller automatically regulates or limits operation in order to prevent a set maximum demand from being exceeded. With the monitored information, the controller can calculate when an overload of the set demand will occur. The controller will delay any shed action to allow time for loads to shed normally. When it is determined that it will be necessary to shed one or more loads to keep from exceeding the set kilowatt demand, the controller will shed the necessary load. This means that shedding will occur only once during a demand interval and maximum use of available power will be realized.

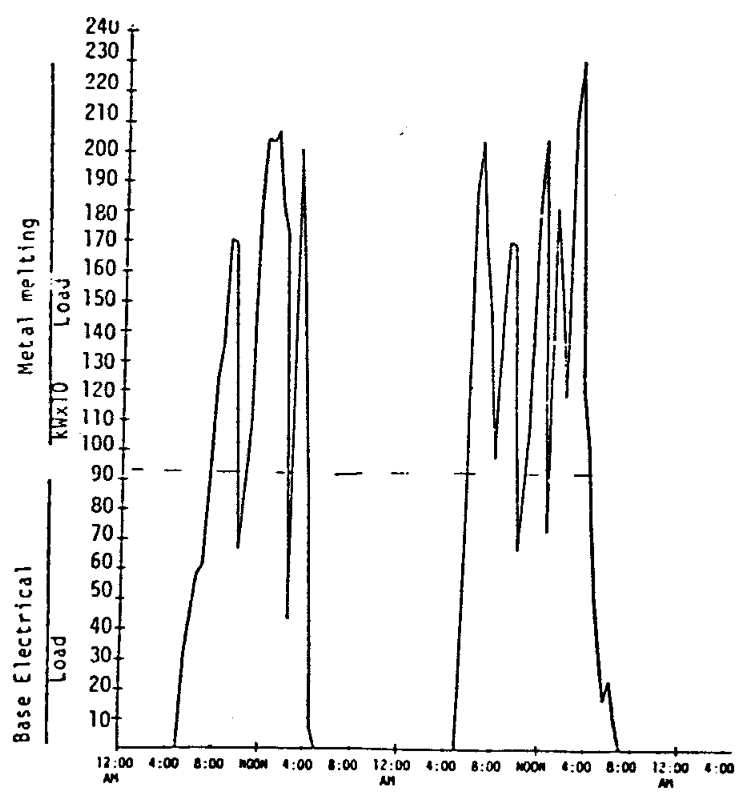


FIGURE 3-5. ELECTRICAL LOAD PROFILE (UNCONTROLLED)

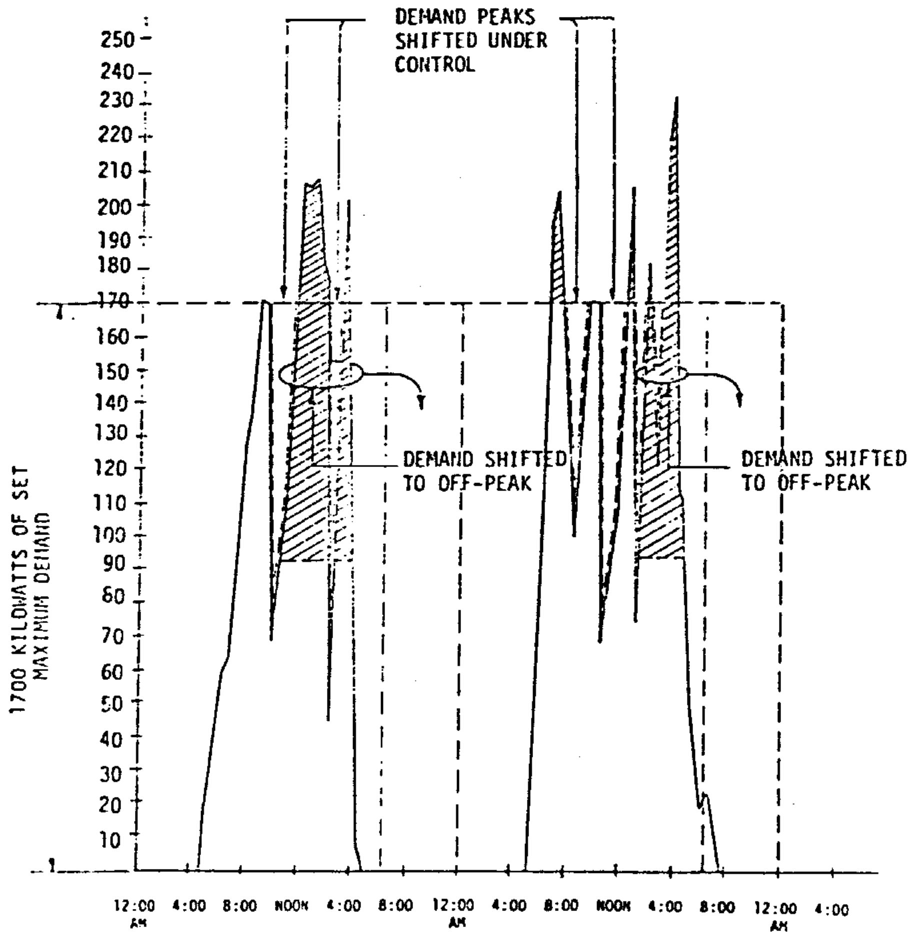


FIGURE 3-6. ELECTRICAL LOAD PROFILE (CONTROLLED)

DEMAND CONTROL

With a power demand controller installed on the power system supply to the furnaces, maximum kilowatt demand can be controlled.

The controller automatically regulates or limits operation in order to prevent a set maximum demand from being exceeded. The controller predetermines the demand limit and the demand interval. The sequence of operation is similar to that described under "load shifting and control".

Figure 3-7, illustrates the new load profile with demand set at 1,700 kW. Cost savings are the same as those computed under "Load Shifting and Control."

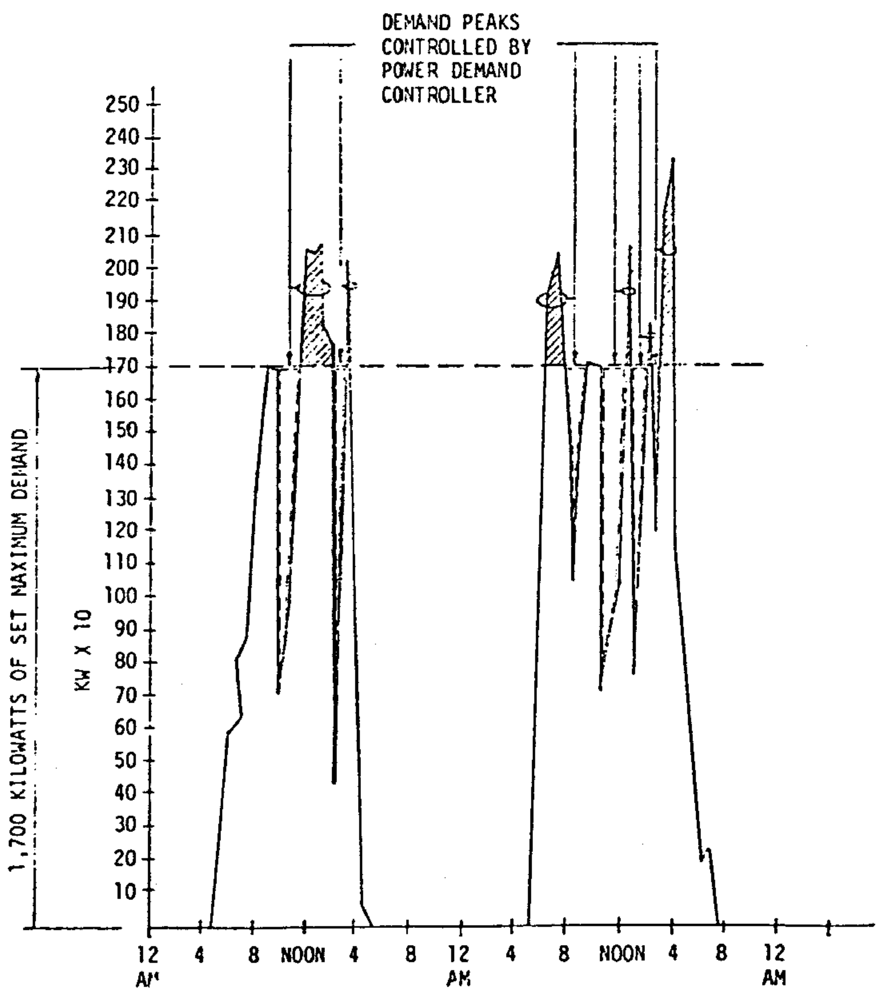


FIGURE 3-7. ELECTRIC LOAD PROFILE (DEMAND CONTROL)

POWER FACTOR CORRECTION

The electrical efficiency of the coreless induction furnace is approximately 76-81 percent with a power factor of approximately 90-98 percent, the channel furnace is approximately 94-96 percent with a power factor of 94-98 percent. With these high power factors designed into the furnaces, no additional correction is necessary.

On the other hand arc furnaces have an approximate power factor of 70% if capacitors are not installed on furnace transformers. It should be noted that power factor improvement will not save in-plant energy or reduce the customer's power bill, but will save energy at the utility company power plant thereby reducing the nation's dependence on oil.

IMPROVED FURNACE DESIGN

Induction Furnaces

An improved profile of the power coil reduces the magnetic flux lines penetrating through the outside corners, which in turn minimizes eddy current loss, thereby improving furnace efficiency.

Use of castable backup refractory will eliminate the need for cooling coils and save the energy that would otherwise enter into the cooling water. The efficiency of the furnace can be increased as much as 10% with these improvements. A foundry producing 25 tons a day can save approximately per year. Using representative figures for this example the savings compute as follows:

Total energy required to melt 25 tons of metal per day =

$$\frac{25 \text{ x } 500 \text{ kwh/ton}}{0.76\% \text{ efficiency}} = 16{,}500 \text{ kwh}$$

10% improvement = 16,500 x 0.10 = 1,650 kwh savings/day

Savings/year at 240 days = 1,650 x 240 = 400,000 kwh

Arc Furnaces

The installation of water-cooling on the sidewalls of the furnace will reduce downtime necessary for refractory replacement. With installation of water-cooled blocks there is about 10% increase in total furnace productivity; other benefits are:

- 80% decrease in sidewall brick consumption

- Reduction of power "on-time" by 13%

- 3% energy savings

- 8% reduction in electrode consumption

The installation of solid-state furnace controls provides for automatic positioning of the electrodes within the furnace. The control maintains the arc setpoint more accurately which gives constant power input and longer refractory life. Constant arc stability provides for a higher through-put, with a higher input power usage. The energy savings that can be realized are approximately 10 percent.

Electric Resistance Reverberatory Melting Furnace (ERMF)

Installation of furnace covers over the charging and dipout wells and the bath will save energy.

Sample Calculation

Potential energy savings in covering a four-square-foot opening based on radiation losses of 20,000 Btu's/SF/hr for covered furnaces.

Four Ft^2 Area

Losses without cover	= (4 x 20,000)	=	80,000 Btu/hr
Losses with cover	= (4 x 500)	=	2,000 Btu/hr
Net reduction		=	78,000 Btu/hr
Losses per 10-hr day	= (78,000 x 10)	=	780,000 Btu
kwh saved (780,000 . 3412)		=	228 kwh

Graphite Rod Holding Furnace

As the graphite rod holding furnace is not a primary melting furnace, this furnace will not be addressed with regards to lost energy. The efficiency and utilization of energy input for metal holding is high. The power factor is maintained at near unity with this type of unit.

B. NATURAL GAS MELTING

GENERAL CONSIDERATIONS

This section deals with energy savings in gas melting operations:

Formulas, calculations, and graphs have been simplified within the Scope of the Project to reflect constant conditions during the process.

To investigate any process in depth, it is essential to establish parameters, calculate the data and plot results on a continuous basis to establish the limits of the operation and equipment, and identify any trends.

The work sheet lists the expected parameters for furnaces, burner and ancillary equipment and operational data to complete a "one shot" energy audit. This constitutes a base for any further improvements. A tape measure, thermometer, flue gas analyzer and flow meters will be the tools needed.

TABLE 3-IV. GAS FURNACE DATA INPUT

Metal type: Aluminum Annual tons 1,500

Pouring or tap temperature 1380 ^{o}F

* Heat content Btu/lb 497 Shifts/day One

Melting period hrs. 8 Holding period hrs. 16

Method of Melting	Crucible	Reverb
Metal melted/hr. lbs.	2,000	2,000
Burner rating Btu/hr	3.6×10^6	4.85×10^6
Total gas usage/hr CFH	3,600	4,850
Capacity of furnace lbs.	2,000	5,000
Crucible diameter	36"	-
Area of metal radiation sq. ft.	4.0	4.0
Area of refractory wall:		
Below metal sq. ft.	110	40
Above metal sq. ft.	-	40
Thickness of wall ins.	6	6
Door open area or dip well sq. ft.	-	-
Mean temperature of walls ^{o}F	-	-
Outer temperature of wall T_1	$100^{o}F$	$100^{o}F$
Inner temperature of walls T_2	$3,000^{o}F$	$2,000^{o}F$
Present refractory K value	N/A	6
Proposed refractory K value	-	-
Rs value for refractory	-	-
CO_2 flue gas reading	5 % CO_2	
Combustion air cfm	N/A	N/A
Combustion air wg	N/A	N/A
Flue gas temperature	1,150°F	$1,600^{o}F$
Ambient temperature ^{o}F	-	-
Time of day used	-	-
Days/year used	240	240

* See Figure 3-8 for input data.

GRAPHS, TABLES AND CHARTS

The following graphs, tables and charts illustrated here are to be utilized for performing sample calculations for anticipated energy reduction measures.

Heat Content of Metals

The following graph (Figure No. 3-8) shows the heat content of numerous metals and alloys for various temperature ranges:

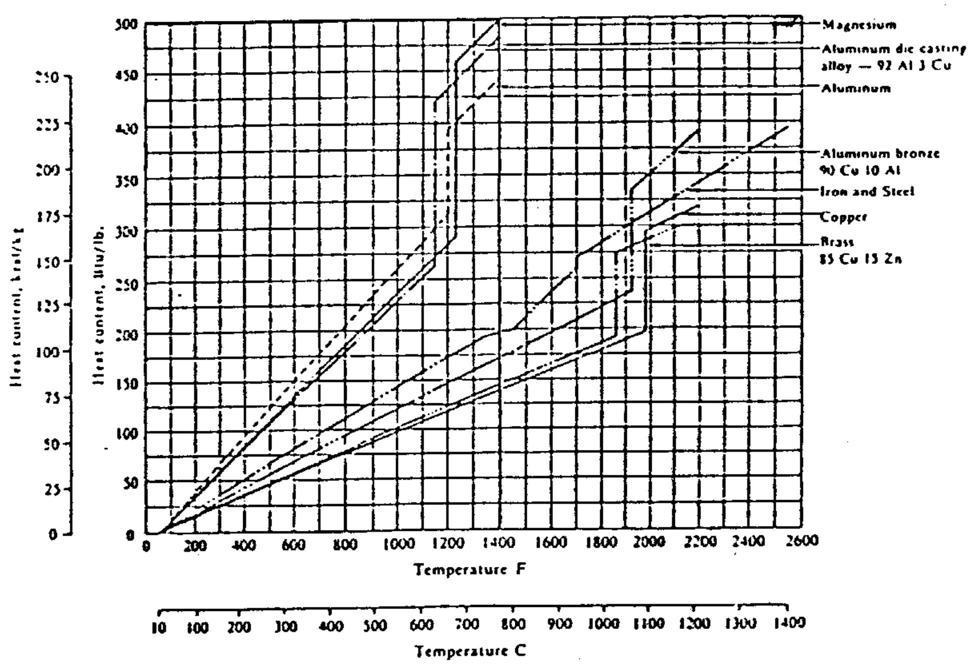


FIGURE 3-8. HEAT CONTENT OF METALS

Example of use: With a 1400° F metal temperature, the heat content of aluminum die casting alloy is approximately 500 BTU/lb.

PERCENT EXCESS AIR FROM CO_2 READING

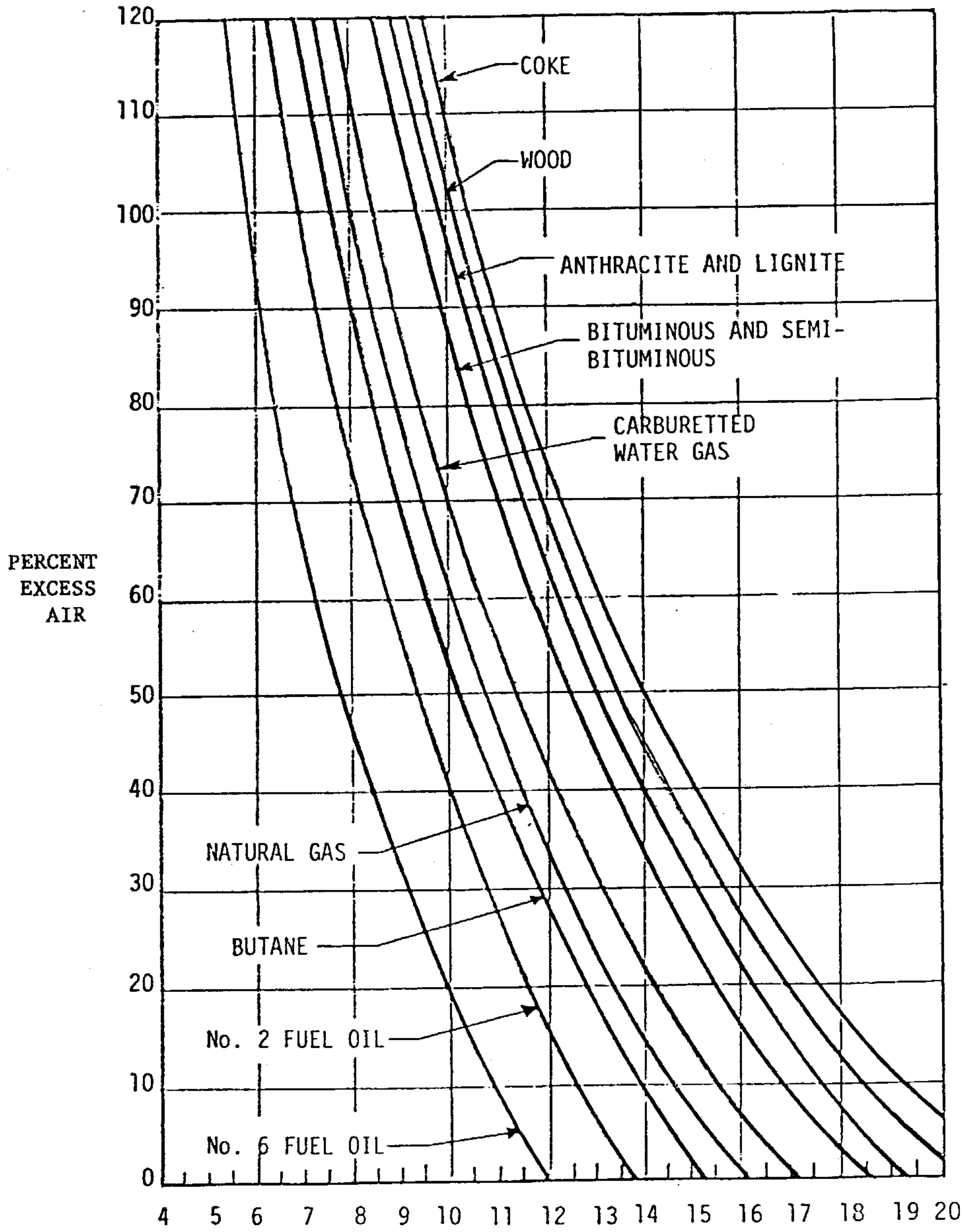
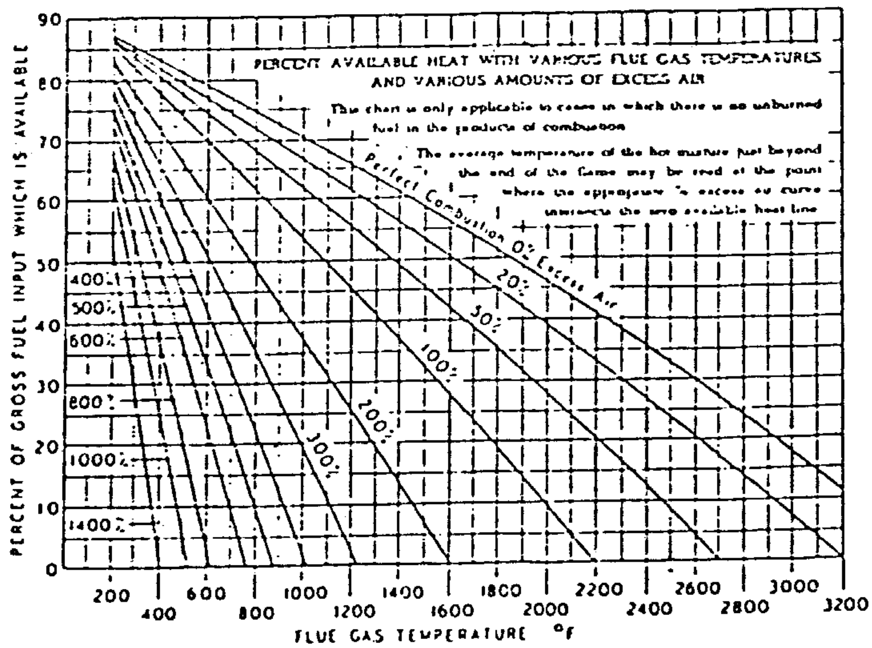


FIGURE 3-9. BURNER CHARACTERISTICS

Source: North American Combustion Handbook.
Example of Use: A combustion analysis shows 6% CO_2 content o the flue gas, with natural gas burning equipment the excess air is approximately 90%.

FIGURE 3-10. PERCENT AVAILABLE HEAT

From North American Combustion Handbook



This chart is only applicable to cases in which there is no unburned fuel in the products of combustion.

The average temperature of the hot mixture just beyond the end of the flame may be read at the point where the appropriate "% Excess Air" curve intersects the zero available heat line.

Example of use: With a flue gas temperature of 1100o F and an excess air requirement of 90%, the amount of heat available for metal melting (including heat lost by radiation) is approximately 52%.

TABLE 3-V. TYPICAL THERMAL PROPERTIES OF REFRACTORY AND INSULATING CONCRETES

Aggregate.	Fired density, lb. per cub. ft.	Heat capacity, B.t.u. per (cub. ft.) (deg. F.)	Thermal conductivity, B.t.u. per (hr./sq. ft.) (deg. F. per in.)	Thermal diffusivity, (sq. ft. per hr.)
Vermiculite ..	35	9	1.2	0.011
Diatomite	55	14	1.7	0.010
Crushed H.T. Insulating brick ..	85	21	3.2	0.013
Expanded clay ..	90	22	3.5	0.013
Crushed firebrick ..	115	29	6	0.017
Molochite ..	120	31	8	0.021
Sillimanite	135	33	10	0.025
Carborundum ..	145	40	50	0.103
Calcined bauxite ..	160	45	12	0.022
Magnesite	160	45	20	0.037
Chrome-magnesite ..	165	37	8	0.018
Fused magnesia ..	170	50	24	0.04
Fused alumina ..	175	52	16	0.026
Bubble alumina ..	95	22	6	0.023

Example of use: Read "K" (thermal conductivity) for type of lining in use.

PHYSICAL PROPERTIES*

	2100	2400	2600	2800	3000
Maximum Recommended Use Temperature	2100°F (1150°C)	2400°F (1315°C)	2600°F (1425°C)	2800°F (1540°C)	3000°F (1650°C)
Density (PCF)	12-15	18-22	18-22	18-22	18-22
Thermal Conductivity - k (BTU - In./S.F. - °F - Hr.)			Same k values for these compositions.		
Mean Temperature °F 600°F	0.26	0.29			
800°F	0.36	0.35			
1000°F	0.48	0.41			
1200°F	0.62	0.48			
1400°F	0.77	0.57			
1600°F	0.93	0.67			
1800°F	1.08	0.79	"k" measurements made at		
2000°F	1.24	0.93	Refractories Research Center,		
2200°F	-	1.10	Ohio State University.		
2400°F	-	1.30			

Ref. Industrial Insulations, Inc.

TABLE 3-VI. THERMAL PROPERTIES

Example of use:

Determine mean temperature from formula; $\frac{t_1 - t_2}{2}$ = Mean wall temp.

Read "K' thermal conductivity under maximum recommended use temperature.

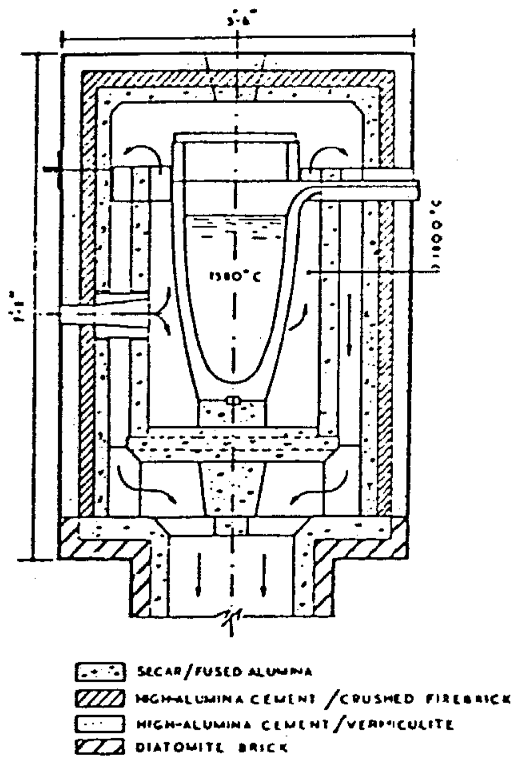


FIGURE 3-11

Composite refractory- and insulating-
concrete lining of a propane-fired furnace

Example of K values for above material

Fused alumina,	K = 16
Crushed Firebrick,	K = 6
Vermiculite,	K = 1.2
Diatomite Brick,	K = 1.7

TABLE 3-VII. HEAT STORAGE AND LOSSES BTU/SQ. FT.

WALL THICKNESS	TYPE REFRACTORY	HOT FACE TEMPERATURE °F					
		1,200		1,600		2,000	
		H. ST.	H.L.	H. ST.	H.L.	H. ST.	H.L.
9"	Composite 2,000° insulation and firebrick	13,700	285	19,200	437	24,800	615
13-1/2"	Composite 2,000° insulation and firebrick	22,300	335	31,400	514	40,600	718
22-1/2"	Composite 2,000° insulation and firebrick	43,200	182	61,000	281	79,200	392
6"	Ceramic fiber	842	208	1,170	432	1,490	672

H. ST. - Heat Stored
H. L. - Heat Lost. BTU/Hr.

PREHEATING OF COMBUSTION AIR

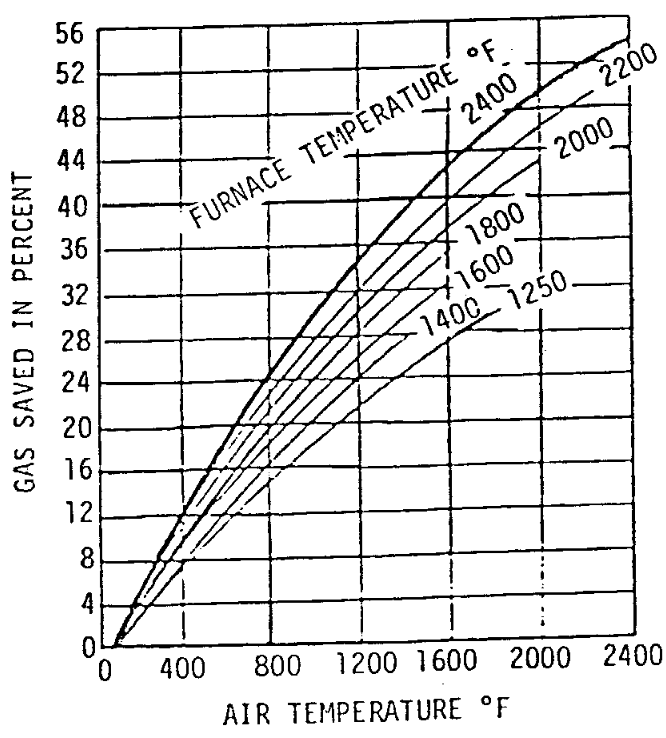


FIGURE NO. 3-12

Example of use: Read gas saved in percent against furnace temperature curve for combustion air temperature obtained.

At 1600° F furnace temperature, and 1200° F air temperature, the gas saved is approximately 26 percent.

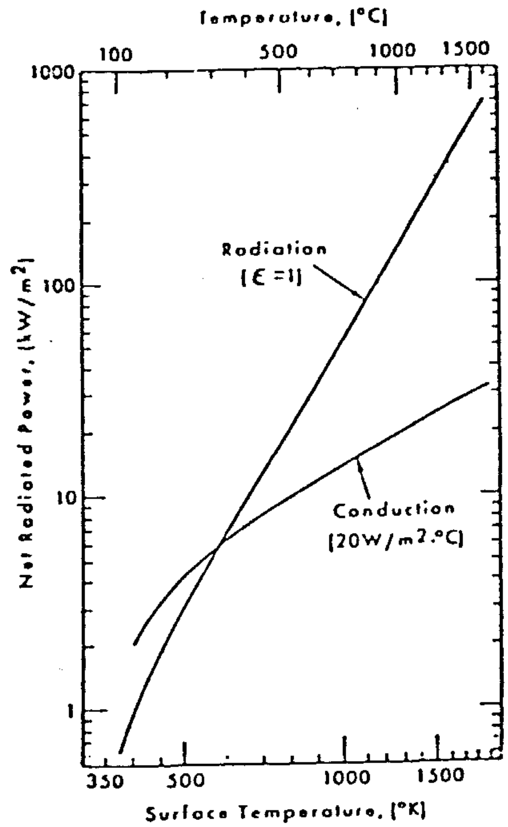


FIGURE 3-13

Example of use: Read net radiation (kw/m^2) against surface temperature and radiation curve.

e.g. at 800° C, radiated power is approx. 100 kw/m^2.
Where 800° C = 1472° F.
100 kw/m^2 = 30,000 BTU/sq. ft.

IMPROVING COMBUSTION EFFICIENCY

Example: A crucible furnace melts 2,000 lbs. of aluminum per hour, flow meter readings indicate that 3,500 cu. ft. of gas per hour (3.5×10^6 BTU/hr.) is used.

Flue gas temperature was measured at 1150° F and the flue gas analysis showed a CO_2 content of 5%. Find present combustion efficiency and probable efficiency, by installation of a nozzle mix burner and fuel/air ratio controls, if CO_2 content was corrected to 11% and excess air reduced to 10%. For this example it has been assumed that furnaces are equipped with covers.

Present Combustion Efficiency

Heat required to melt aluminum,

- Heat content of metal is 500 BTU/lb (Figure No. 3-8)
- Amount of metal heated per hour is 2,000 lb.

Therefore, heat to product is 500 x 2000 = 1,000,000 BTU/hr.

Heat lost to exhaust.

- From Figure No. 3-9 with 5% CO_2 in flue gas the excess is approximately 130%.
- From Figure No. 3-10 with a flue gas temperature of 1150° F and 130% excess air, the percent of gross fuel input available to do work (including radiation losses) is approximately 40%.

Therefore, of the 3,500,000 BTU/hr. energy input only (3,500,000 x 0.4) 1,400,000 BTU/hr (minus the radiation losses) is utilized.

Probable Combustion Efficiency

Heat lost of exhaust

- From Figure No. 3-9 with 11% CO_2 in flue gas the excess air is 10% approximately.
- From Figure No. 3-10 with a flue gas temperature of 1150° and 10% excess air, the percent of gross fuel input available to do work (including radiation losses) is approximately 65%.

Therefore, of the 3,500,000 BTU/hr. energy input (3,500,000 x 0.65) 2,275,000 BTU/hr. is available for melting the metal.

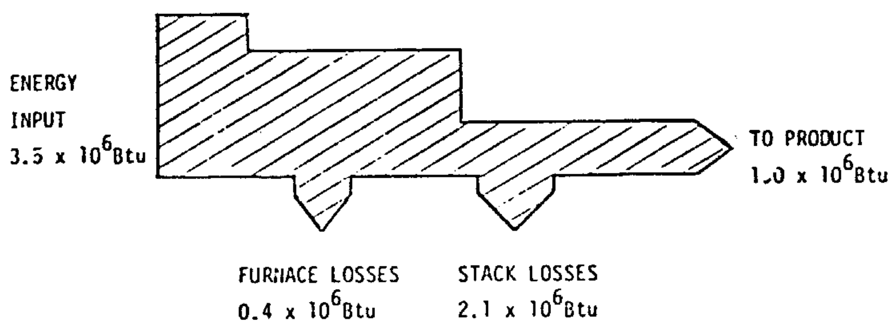
As previously stated the amount of heat required to melt 2,000 lbs. of aluminum is 1,000,000 BTU/hr. Present combustion efficiency calculations show that 1,400,000 BTU/hr. was available to melt the metal. Therefore: 1,400,000 - 1,000,000 results in 400,000 BTU/hr. being lost by radiation effects. By increasing the available fuel to 65% it can be readily seen that a smaller burner could be used to accomplish the same work.

$$\frac{875{,}000 \text{ BTU/hr.}}{350{,}000 \text{ BTU/hr.}} \times 100 = 25\% \text{ less fuel}$$

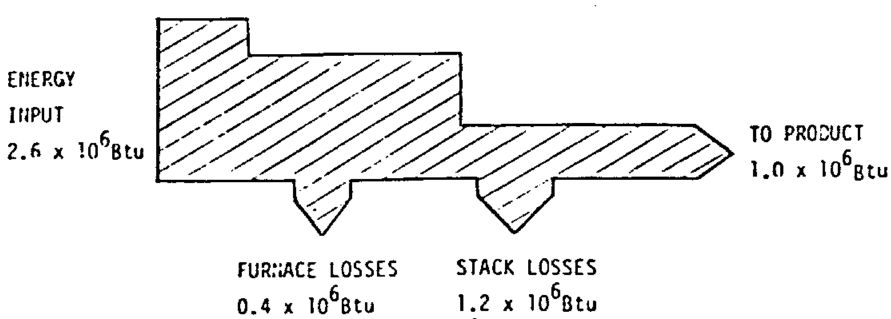
Summary

Item	Present Energy	Probable Energy
Heat to product	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Heat loss to Stack	2,100,000 BTU/hr.	1,225,000 BTU/hr.
Heat loss (Radiation)	400,000 BTU/hr.	400,000 BTU/hr.
Gross Input	3,500,000 BTU/hr.	2,625,000 BTU/hr.

Process Energy Flow Diagrams

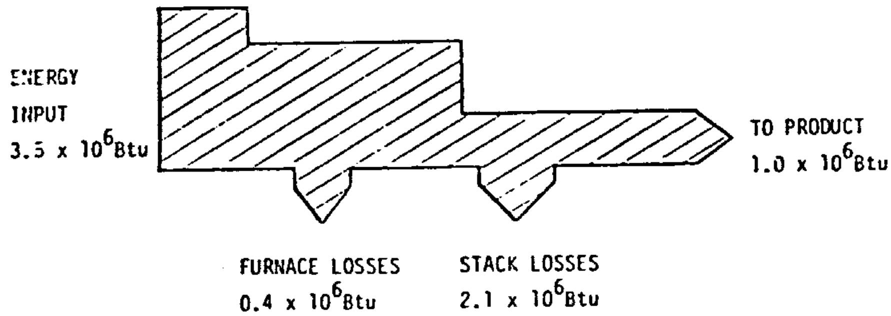


PRESENT CONDITION

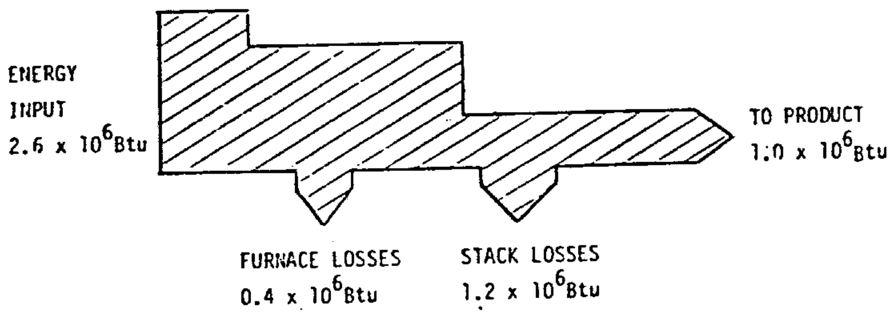


PROBABLE CONDITION

Process Energy Flow Diagrams



PRESENT CONDITION



PROBABLE CONDITION

Yearly Energy Savings

Assuming, using the above example, that the furnace melted 8 hours per day, 5 days per week, 50 weeks per year then the energy savings would be:

8 x 5 x 50 x 875,000 BTU/hr. = $\underline{1750 \times 10^6 \text{ BTU}}$ or 17500 therms/year,

COMBUSTION AIR PREHEATING

For typical gas fired furnace with flow rate of 3.5×10^6 BTU/hr, improved efficiency can be attained by preheating the combustion air with the use of a hot gas recuperator.

Example Calculations

With flue gas temperature of 1600° F, if combustion air is pre-heated to 1200° F, energy savings of approx. 26% are available as obtained from Fig. 3-12. Thus heat savings can be calculated for the typical gas fired furnace as follows:

$$2.625 \times 10^6 \text{ BTU/hr.} \times 0.26 = 0.68 \times 10^6 \text{ BTU/hr.}$$

Annual energy reduction based on 8 hours/day, 240 days per year is

$$\frac{0.68 \times 10^6 \times 8 \times 240}{100{,}000 \text{ BTU/therm}} = 13{,}100 \text{ therms/yr.}$$

Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Stack Losses*	1.225,000 BTU/hr.	545,000 BTU/hr.
Radiant Losses*	400,000 BTU/hr.	400,000 BTU/hr.
Gross Input	2,625,000 BTU/hr.	1,945,000 BTU/hr.

*Stack and radiant losses from previous example after improvements

REFRACTORY MATERIALS - CRUCIBLE FURNACE

Sample Calculation -

A crucible furnace with composite refractory and insulating - concrete lining is compared to same furnace with ceramic fiber sleeve insulating material. Diagram of typical furnace with composite lining is shown in Fig. 3-11.

The heat loss through composite material is determined by calculation of "Q".

$$Q \text{ per sq. ft.} = \frac{t_1 - t_2}{R_1 + R_2} \text{ etc.}$$

Where t_1 = Hot Face Wall Temperature.
t_2 = Cold Face Wall Temperature.
R = Resistance, which is the wall thickness divided by "K", the conductivity of the material.

"K" for various materials is obtained from table of typical thermal properties (Table 3-V). Thus $R_1 + R_2$ etc. for various thicknesses is:

$$R1 = \frac{2}{16} \text{ (fused alumina)} = 0.125$$

$$R2 = \frac{3}{6} \text{ (crushed firebrick)} = 0.333$$

$$R3 = \frac{1}{1.2} \text{ (vermiculite)} = 0.833$$

$$\text{Total } R_1 + R_2 + R_3 = \overline{1.291}$$

Area of side walls estimated to be 110 sq. ft.

Thus heat loss through composite material = Qa

$$\therefore Qa = \frac{(3{,}000 - 100)\ 110}{1.291} = 247{,}000 \text{ BTU/hr.}$$

NOTE: The above calculation demonstrates the methodology used for computing sample radiation losses. Actual radiation losses used throughout the preceding examples is 400,000 BTU/Hr.

Replace 6" composite material with 6" ceramic fiber sleeve of 3,000° F maximum use temperature. The calculation of mean temperature =

$$\frac{t_1 - t_2}{2} = \frac{3{,}000 - 100}{2} = 1450^{\circ} \text{ F}$$

K value for mean temperature of 1450° F (from Table 3-VI) is prorated between 0.57 and 0.67 to be 0.60

$$\text{thus R (ceramic fiber)} = \frac{6}{0.60} = 10$$

Thus heat loss through ceramic fiber sleeve = Qb

$$\therefore Qb = \frac{(3{,}000 - 100)\ 110}{10} = 31{,}900 \text{ BTU/hr}$$

Change in heat loss Qa - Qb = 247,000 - 31,900 = 215,100 BTU/hr

If original energy input is 1.945 x 10^6 BTU/hr., the furnace efficiency is improved from 51.4 per cent to approximately 57.8 percent, or 6.4% increase in efficiency.

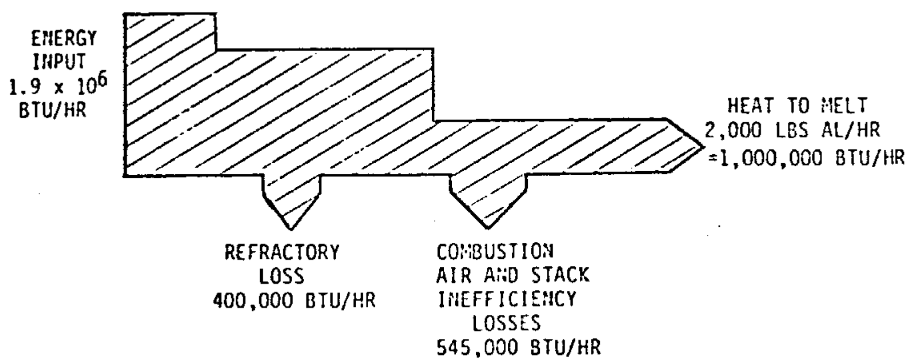
Summary

Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Radiation Loss*	400,000 BTU/hr.	185,000 BTU/hr.
Radiant Losses*	545,000 BTU/hr.	545,000 BTU/hr.
Gross Input	1,945,000 BTU/hr.	1,730,000 BTU/hr.

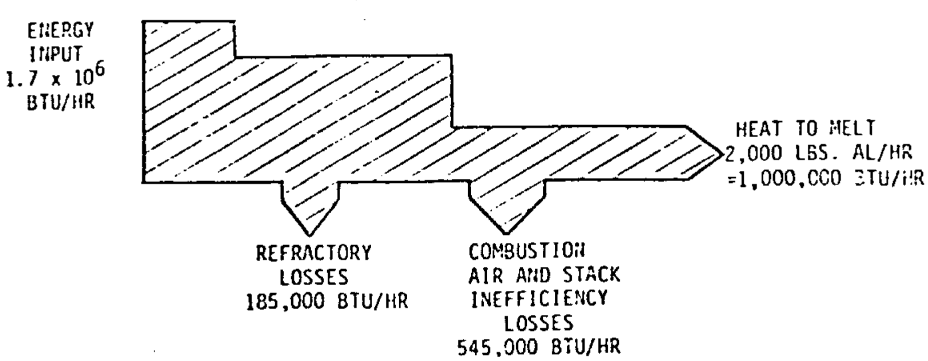
*Stack and radiant losses from previous example after improvements of combustion equipment.

TYPICAL ENERGY FLOW DIAGRAM

PRESENT CONDITION:



PROBABLE CONDITION:



FURNACE COVERS

Ladle and furnace covers eliminate most of the radiation loss which is the major area of energy loss from uncovered ladles and metal surfaces. Net radiated heat loss from a metal surface, emissivity, depends on the amount of slag. Emissivity of clean iron is relatively small but the thin slag layer usually present increases emissivity. Energy loss can be obtained by reference to Fig. 3-13 by reading net radiated power at metal temperature from the chart.

Example, at metal temperature of 800° C (1472° F), read for radiation at E = 1, net radiated power = 100 kw/m^2 (0.03×10^6 BTU/sq.ft.)

Where: $1\ m^2 = 10.76$ sq.ft.

1 kw = 3412 BTU.

Sample Calculation–

Consider a gas fired furnace holding aluminum at 1400° F with dip well area 4 sq. ft. without a cover and calculate the energy savings with a ceramic fiber cover in place.

Radiation losses, at 1400° F (760° C) from Fig. 3-13 = 60 kw/m^2

= 19,000 BTU/sq.ft.

Thus 4 sq.ft. x 19,000 BTU = 76,000 BTU/hr.

Heat loss from dip well with cover, based on thickness of two inches for ceramic fiber cover, is:

$$Q = \frac{t_1 - t_2}{R_1 + R_2} \text{ etc.}$$

where t_1 = hot face temp. 1400° F.
t_2 = cold face temp. 200° F.
R = Resistance which is the thickness of the cover divided by the conductivity K.

K for cover material can be obtained from Table 3-V where mean temperature of the material is given by

$$\text{Mean temp.} = \frac{t_1 - t_2}{2} = \frac{1400 - 200}{2} = 600^{\circ}\text{F}$$

Thus K from Table 3-V at 600° F = 0.26 (BTU/sq. ft. per ins - $^{\circ}$F/hr.)

$$\therefore Q = \frac{(1400 - 200)\ 4 \text{ sq. ft.}}{2/0.26} = \frac{4800}{7.7} = 600 \text{ BTU/hr.)}$$

Savings in energy loss = 76,000 - 600 = 75,400 BTU/hr.

With cover in place during 16 hours holding period per day, the reduction in energy for 240 days per year is:

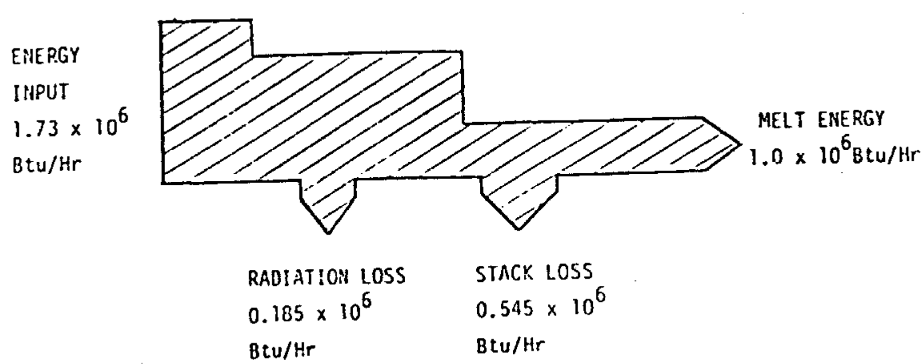
$75,400 \times 16 \times 240 = 289 \times 10^6$ BTU year

Summary

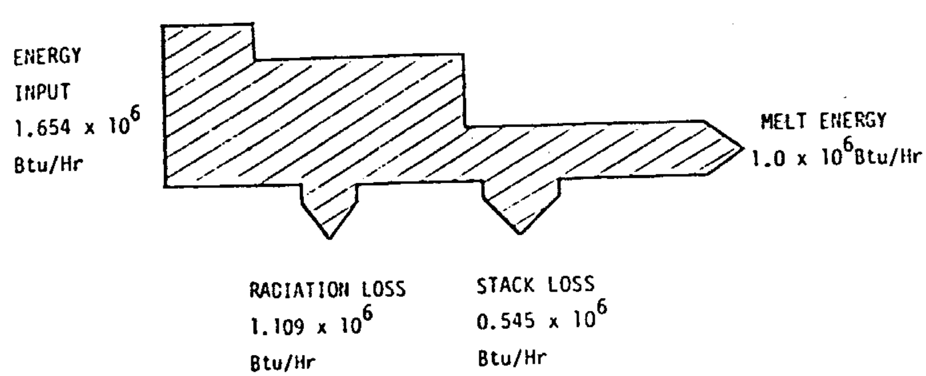
Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Radiation Loss*	185,000 BTU/hr.	109,600 BTU/hr.
Radiant Losses*	545,000 BTU/hr.	545,000 BTU/hr.
Gross Input	1,730,000 BTU/hr.	1,654,600 BTU/hr.

*Stack and radiant losses from previous example for present conditions after improvements.

PRESENT CONDITION -



PROBABLE CONDITION -



OVERALL FURNACE EFFICIENCY

The following table summarizes the probable cost and energy savings by carrying out all of the possible improvements previously covered in the examples.

Summary (Energy and Cost Savings)

Item	BTU/hr. Reduction	Efficiency Percent Increase	Annual Gas Therms.
Combustion Efficiency	875,000	25.0%	17500
Preheat Comb. Air	680,000	26.0%	13100
Refractory Upgrade	215,000	6.4%	4130
Furnace Covers	75,000	2.6%	2900
Total	1,845,000	31.8	37,630

$$\text{Overall Thermal Efficiency} = \frac{1.0 \times 10^6}{(3.5 - 1.845)\ 10^6} \times 100 = 60.4\%$$

Present Efficiency (Approximate) = 28.6%

Increased Efficiency = 60.4 - 28.6 = 31.8%

$$\text{Percent Energy Saved} = \frac{1,845,000}{3,500,000} = 53\%$$

REVERBERATORY FURNACES

Energy savings and efficiency improvements can be developed for reverberatory furnaces. For combustion efficiency and burner preheating the previous examples are repeated and applied to reverberatory furnace summary analysis.

Sample Calculation -

Assume a reverberatory furnace melts 2,000 lbs of aluminum per hour. The area of refractory below metal is 40 sq. ft. and the area of refractory above metal is 40 sq. ft. Thickness of refractory is 6 inches. Metal is at 1380° F and combustion gas temperature above the metal is 3000° F. To find heat loss with conventional refractory, the thermal conductivity k for the material is determined from Table 3-V to be 6 BTU/hr. per sq. ft. (deg. F per inch.) for crushed firebrick.

Heat loss $Q = \dfrac{t_1 - t_2}{R1 + F_2}$ etc.

Where t_1 = Hot Face Wall Temperature.
t_2 = Cold Face Wall Temperature.
R = Resistance, which is the wall thickness of the lining divided by the conductivity of the material K.

Mean temperature $\dfrac{t_1 - t_2}{2}$ is required to select K

Thus the mean temperature for area above the metal, based on a

combustion gas temperature of 3000° F $= \dfrac{3000 - 100}{2} = 1450°$ F

Mean temperature for area below the metal $= \dfrac{1380 - 100}{2} = 690°$ F

$\therefore$ Qa (above the metal) $= \dfrac{3000 - 100}{6/6} = 2900$ BTU/Hr/Sq. Ft.

$= 2900 \times 40 = 116{,}000$ BTU/hr.

$\therefore$ Qb (below the metal) $= \dfrac{1380 - 100}{6/6} = \dfrac{1280}{1} = 1280$ BTU/hr/sq/ft.

$= 1280 \times 40 = 51{,}200$ BTU/hr.

$\therefore$ Total heat loss through the refractory walls

= Qa + Qb = 116,000 + 51,200 = <u>167,200 BTU/hr.</u>

To find the heat loss with ceramic lining used for insulation between the refractory and the outer shell, the added R, resistance, must be calculated.

The thermal conductivity K for ceramic fiber is determined from Table 3-V for 1 inch thick material to be 0.26 BTU/hr. per sq. ft. (deg. F per inch.)

Note - Mean temperature assumed between refractory and shell, $t = 200^{\circ}$ F.

$$\therefore \quad \text{New heat loss } Qa + Qb = \frac{(t_{1a} - t_2)\ 40}{6/6 = 1/0.26} + \frac{(t_{1b} - t_2)\ 40}{6/6 + 1/0.26}$$

$$= \frac{(3000 - 100)\ 40}{1 + 3.84} = \frac{(1380 - 100)\ 40}{1 + 3.84} = 23{,}970 \quad + 10{,}600$$

= <u>34,570 BTU/hr.</u>

Change in heat loss through lining by adding 1 inch of ceramic fiber insulation = 167,200 - 34,570 = 132,630 BTU/hr. reduction, equivalent to 79.3% savings.

Summary

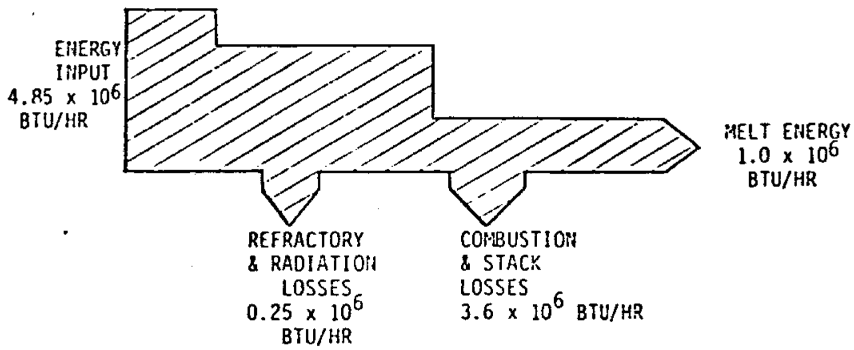
Item	Present Energy	Probable Energy
Heat to Melt	1,000,000 BTU/hr.	1,000,000 BTU/hr.
Radiation Losses*	250,000 BTU/hr.	117,000 BTU/hr.
Combustion and Stack Losses*	2,045,000 BTU/hr.	2,045,000 BTU/hr.
Gross Input	3,295,000 BTU/hr.	3,162,000 BTU/hr.

* Combustion and stack losses from previous example after improvements are listed in this case for present energy use.

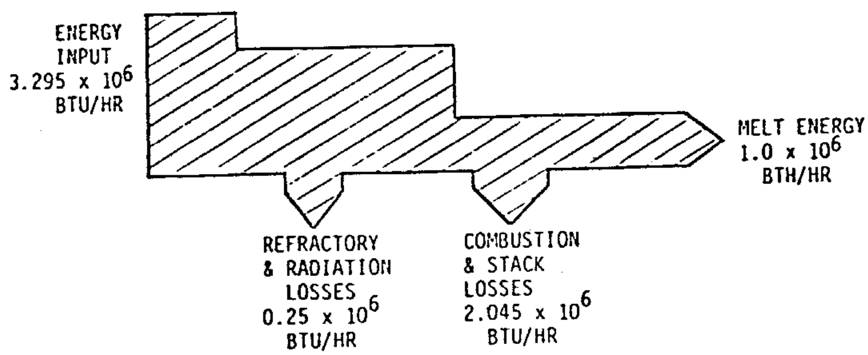
Energy flow diagrams for all improvements by progression from original condition to ultimate condition are as follows:

Energy Flow Diagrams - Reverberatory Furnace Example

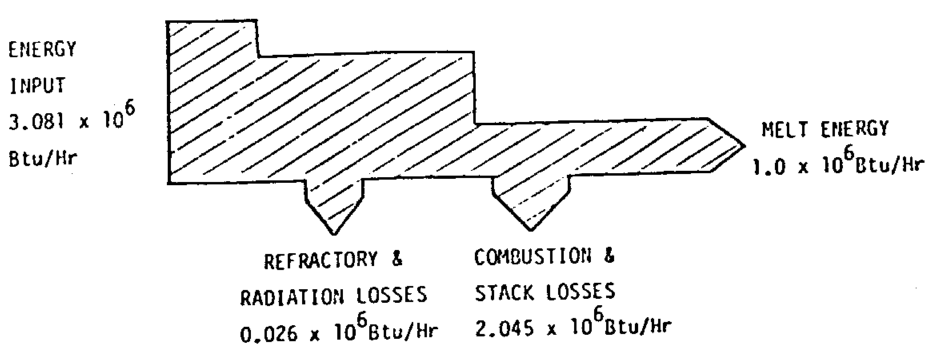
ORIGINAL CONDITION:



COMBUSTION IMPROVEMENT & BURNER AIR PRE-HEAT



REFRACTORY & METAL COVERS IMPROVEMENTS



OVERALL FURNACE EFFICIENCY

The following table summarizes the probable energy saving available by carrying out all of the possible improvements in common with the crucible furnace per previous examples.

TABLE 3 - VIII. SUMMARY (ENERGY AN COST SAVINGS)

ITEM	BTU/HR REDUCTION	% ENERGY SAVING	ANNUAL GAS THERMS
Combustion Efficiency*	875,000	25.0%	17,500
Preheat Combustion Air	680,000	26.0%	13,100
Refractory Upgrade	132,000	4.0%	2,550
Furnace Covers	75,000	2.1%	2,900
TOTAL	1,762,000		36,050

Overall percent energy reduction $= \dfrac{1,762,000}{4,850.000}$ $= 36.3\%$

Overall thermal efficiency $= \dfrac{1.0 \times 10^6 \times 100}{(4.85 - 1.762 \times 10^6)}$ $= 32.3\%$

Present efficiency (approximate) $= 20.6\%$

Increased efficiency $= 32.3 - 20.6$ $= 11.7\%$

HEAT TREATING

General Considerations

This section, dealing with the energy savings obtainable in the Heat Treat Furnace operation, will concentrate generally on the major areas for energy savings attributed to:

- Process operation and control
- Refractory materials
- Combustion equipment
- Heat recuperation

Formulas, calculations, and graphs have been simplified with the Scope of the Project to reflect constant conditions during the process.

To investigate any process in depth it is essential to establish parameters, circulate the data and plot results on a continuous basis to establish the limits of the operation and equipment, and identify any trends.

The work sheet lists the expected parameters for furnace shell, blower, burner and ancillary equipment, and operational data to complete a "one shot" energy audit and constitute a base for any future improvements. A tape measure, thermometer, flue gas analyzer and flow meters will be the tools needed.

FIGURE 3-14. HEAT TREAT DATA INPUT

HEAT TREATING UNIT NO. 1	
FURNACE MAKE ANY	BURNER MAKE ABC
MODEL ANY	MODEL ABC
SIZE 10' x 20' x 8' HIGH	TYPE Pre mix SIZE ____ BTU/HR
CAPACITY 20,000 LBS.	FUEL Natural Gas
TYPE OF LINING Conventional	RECUPERATOR MAKE None
WALL THICKNESS 13½ INCH	MODEL - TEMP - °F
BLOWER MAKE ____	TYPE - SIZE -
MODEL ____	CONTROLS MAKE None
SIZE ____ CFM. PRESS ____ "WG	TYPE -
VOLT ____ HP ____	
TYPE OF HEAT TREAT CYCLE ____	ALLOY ____
HEAT TREAT CYCLE - HEATUP ____ HRS	FUEL/AIR RATIO Un-controlled
- SOAK ____ HRS	FLUE TEMPERATURE HIGH 1650 °F LOW ____ °F
-COOL DOWN ____ HRS	SHELL MEAN TEMPERATURE ____ °F
CYCLES PER WEEK ____	FURNACE PRESSURE Negative "WC
TEMPERATURE 1,650 °F	
AVERAGE LOAD ____ LBS	FLUE ANALYSIS (HIGH) N/A % CO
CASTING ____ LBS	N/A % O_2
BASKETS ____ LBS	5 % CO_2
STOOLS ____ LBS	
LOAD DENSITY ____ LBS/WFT	
QUENCH ___ AIR, ___ H2O ___ OIL	
QUENCH TEMPERATURE ____ °F	FUEL CONSUMPTION 116 THERMS/CYCLE

MISCELLANEOUS

WALL AREA 880 SQ.FT.

WALL TEMPERATURE HOT FACE T_1 1650 °F

WALL TEMPERATURE COLD FACE T_2 160 °F

AMBIENT TEMPERATURE 80 °F

EXTERNAL SURFACE AREA 880 SQ.FT.
HOT SURFACE AREA 570 SQ.FT.
ENERGY COST/THERM $ 0.30

HEAT TREAT LOADS/DAY ____

HEAT TREAT LOADS/YEAR ____

Note: Data Recorded is only that needed to perform sample calculations.

TABLE 3-IX

APPROXIMATE THERMAL CONDUCTIVITIES OF FIRECLAY BRICK

Btu per Hour, per Square Foot, per Degree F. Temperature Difference, for One-Inch Thickness

Kind of Brick	Den-sity*	Mean Conductivity at T°F.													
		200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800
	147	9.7	9.7	9.7	9.8	9.9	10.0	10.2	10.3	10.5	10.7	10.9	11.1	11.3	....
	146	8.7	8.8	9.0	9.1	9.3	9.4	9.6	9.7	9.9	10.0	10.2	10.4	10.5	....
	136	8.4	8.5	8.7	8.8	9.0	9.2	9.3	9.5	9.6	9.8	9.9	10.1	....	....
	127	7.1	7.3	7.4	7.6	7.8	8.0	8.1	8.3	8.5	8.7	8.8	9.0	....	....
	125	5.8	6.2	6.5	6.9	7.3	7.6	8.0	8.3	8.7	9.0	9.4	9.8	....	....

*Pounds per Cubic Foot.

NOTE: For brick of the same type, class, composition, and burn, the conductivities are approximately proportional to the bulk densities (weights in pounds per cubic foot).

TABLE 3-X

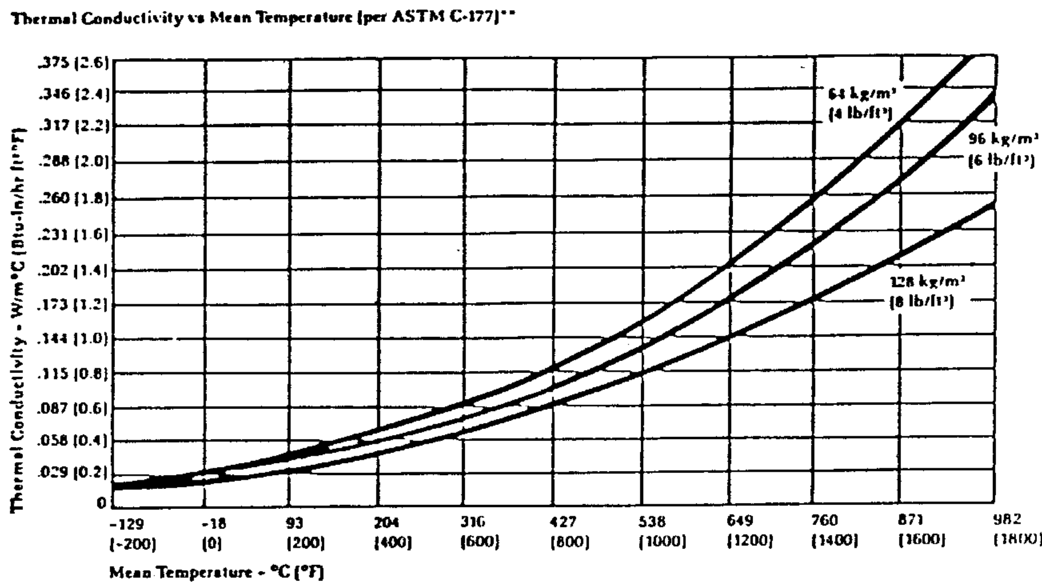
APPROXIMATE THERMAL CONDUCTIVITIES OF INSULATING FIREBRICK

Btu per Hour, per Square Foot, per Degree F. Temperature Difference, for One-Inch Thickness

Den-sity*	Thermal Conductivity at T°F													
	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800
36	1.06	1.20	1.34	1.48	1.63	1.77	1.91	2.05	2.19	....	....	....	....	....
38	1.26	1.40	1.54	1.68	1.83	1.97	2.11	2.25	2.40	....	....	....	....	....
46	1.44	1.59	1.75	1.91	2.06	2.22	2.38	2.53	2.69	2.85	3.00	....	....	....
31	0.78	0.86	0.94	1.02	1.09	1.17	1.25	1.33	1.41	1.48	1.56	....	....	....
49	1.83	1.98	2.13	2.28	2.43	2.58	2.73	2.88	3.03	3.18	3.33	3.48	....	....
56	1.95	2.10	2.25	2.40	2.55	2.70	2.85	3.00	3.15	3.30	3.45	3.60	3.75	3.90
60	2.20	2.35	2.50	2.65	2.80	2.95	3.10	3.25	3.40	3.55	3.70	3.85	4.00	4.15

*Pounds per Cubic Foot

FIGURE 3-15. THERMAL CONDUCTIVITY OF CERAMIC FIBER INSULATION



**All heat flow calculations are based on a surface emissivity factor of .90, an ambient temperature of 27°C (80°F), and zero wind velocity, unless otherwise stated. All thermal conductivity values for Fiberfrax materials have been measured in accordance with ASTM Test Procedure C-177. When comparing similar data, it is advisable to check the validity of all thermal conductivity values and ensure the resulting heat flow calculations are based on the same condition factors. Variations in any of these factors will result in significant differences in the calculated data.

Heat storage and losses can be approximated based on the following Table 3-XI.

TABLE 3-XI. HEAT STORE AND LOSSES BTU/SQ. FT.

WALL THICKNESS	TYPE REFRACTORY	HOT FACT TEMPERATURE °F					
		1,200		1,600		2,000	
		H. ST.	H.L.	H. ST.	H.L.	H. ST.	H.L.
9"	Composite 2,000° insulation and firebrick	13,700	285	19,200	437	24,800	615
13-1/2"	Composite 2,000° insulation and firebrick	22,300	335	31,400	514	40,600	718
22-1/2"	Composite 2,000° insulation and firebrick	43,200	182	61,000	281	79,200	392
6"	Ceramic fiber	842	208	1,170	432	1,490	672

H. ST. - Heat Stored
H. L. - Heat Lost Btu/hr

FIGURE 3-18. EFFECT OF AIR INFILTRATION

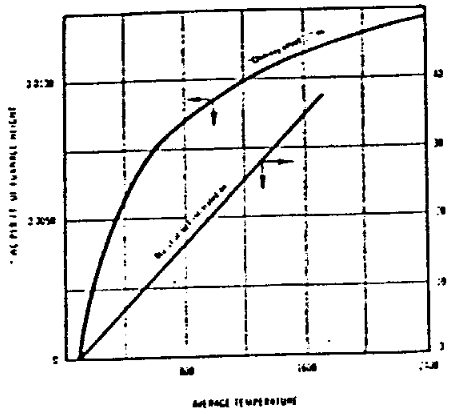


FIGURE 3-18A

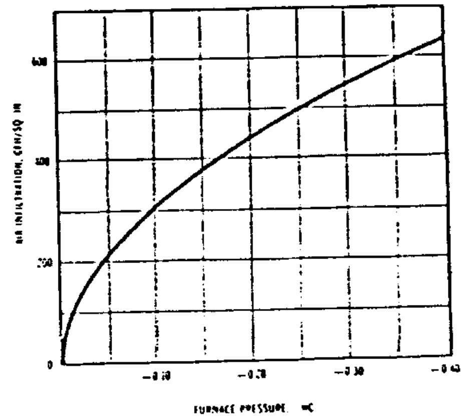


FIGURE 3-18B

Courtesy of American Gas Association

Above table to be used for calculating air infiltration through cracks.

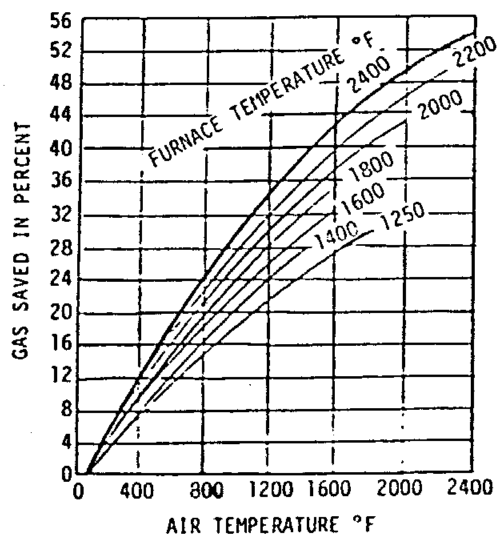


FIGURE 3-19. PREHEATING OF COMBUSTION AIR*

*From AGA Catalog

SAMPLE CALCULATIONS

Upgrading Furnace Linings

Heat loss through various refractory linings can be calculated by the use of the following mathematical formula:

$$\text{HEAT LOSS "Q"} = \frac{T_1 - T_2}{R_1 + R_2} \text{ etc.}$$

WHERE:

t_1 = Hot face wall temperature

t_2 = Cold face wall temperature

R = Resistance, which is the thickness of the lining divided by the conductivity of the material "K"

Typical values of "K", thermal conductivity in Btu/hr, per square foot, per degree "F" temperature difference, for one inch thickness are listed in Tables 3-IX and 3-X for fire clay and brick refractories.

"K" values for ceramic fiber linings are shown in Figure 3-15.

The heat required to get refractories up to furnace operating temperature (heat storage effect) is listed in Table 3-XI.

To obtain "K" factors from Tables 3-IX, 3-X, and Figure 3-15, it is necessary to calculate the mean temperature. This is accomplished by adding t_1 and t_2 and dividing by 2. Thus mean temperature for this set of conditions is:

$$\frac{1650^{o}F - 160^{o}F}{2} = 905^{o}F.$$

Example: Determine heat loss through furnace walls lined with:

(a) Conventional brick refractory lining

(b) Laminated ceramic lining

(c) Full ceramic fiber lining

(a) Conventional refractory lining is composed of the following materials:

- 9" fire brick with a density of 147 lbs/cu. ft.
- 4-1/2" insulated brick with a density of 31 lbs/cu. ft.

Therefore:

$$\text{Heat loss} = \frac{1650 - 160}{91 + 4.24} = \underline{289\ \text{Btu/hr/F}^2}$$

To find resistance "R" for insulated brick, enter Table 3-X at 905° F (mean temperature) and read down to the 31 lb. density column, the resultant "K" factor is approximately 1.06,

$$\text{Therefore } R = \frac{4\text{-}1/2}{1.06} = 4.24$$

Total heat loss through furnace walls:

$= 289$ Btu/hr/ft^2 x 570 sq. ft. = <u>164,730 Btu/Hr.</u>

(b) Laminated refractory lining is composed of:

- 9" fire brick with a density of 147 lb/cu. ft.
- 4-1/2" insulated brick, density of 31 lbs/cu. ft.
- 1" ceramic fiber lining, density of 8 lb/cu. ft.

Therefore:

$$\text{Heat Loss} = \frac{1650 - 160}{.91 + 4.24 + 1.43} = \underline{226}\ \text{Btu/hr/F}^2$$

Total heat loss through furnace walls:

$= 226$ Btu/Hr/F^2 x 570 sq. ft. = <u>128,820</u> Btu/hr.

(c) Full ceramic fiber lining composed of the following:

- 12" ceramic fiber at 8 lbs. density/cu. ft.

Therefore:

$$\text{Heat Loss} = \frac{1650 - 160}{17.14} = 87\ \text{Btu/hr/F}^2$$

To find resistance "R" for ceramic fiber, enter Figure 3-15 at 905^{o} F., extend up to the 8 lb. density column and read 0.7 at the left hand side of the graph, therefore:

$$R = \frac{12}{0.7} = 17.14$$

Total heat loss through furnace walls:

$$= 87 \text{ Btu/hr/Ft}^2 \times 570 \text{ Sq. Ft.} = \underline{49,590} \text{ Btu/hr.}$$

TABLE 3-XII. SUMMARY - HEAT LOSS FOR VARIOUS LININGS

ITEM	Btu/hr	% Savings over Basic Refract.
Conventional Refractory	164,730	-0-
Laminated Refractory	128,820	22%
Ceramic Fiber	49,590	70%

Equivalent total gas usage reduction, utilizing ceramic fiber lining, is 164,730-44,590 = 115,140 Btu/hr or 1.15 Therms per hour.

Based on a continuous heat treat operation (with furnace in equilibrium) of 16 per day, 5 days per week-50 weeks per year, the total yearly gas savings would be as follows:

$$\frac{115{,}140 \text{ Btu/Hr} \times 16 \times 5 \times 50}{100{,}000 \text{ Btu/Therm}}$$

Batch type heat treat operation is very costly in terms of gas usage due to the input energy required to heat the refractory mass up to furnace operating temperature, the following table illustrates the amount of energy required to heat the refractory to 1,600^{o} F. versus that required for ceramic fiber:

TABLE 3-XIII. EFFECT OF USE OF CERAMIC FIBER INSULATION

ITEM	1/Heat Capacity Stored - Btu^{3}	% Savings over Basic Refractory
Conv. Refractory (13-1/2")	17,898,000	
Ceramic fiber (12")	1,333,800	92.5%

*Based on 570 sq. ft. inside furnace area and heat storage figures from Table IV.

Operating batch furnaces on a rapid change-over schedule will realize substantial fuel savings, also consideration must be given to the product to be processed. The scheduling effort to load to design capacity will be more than offset by the fuel savings obtained by reduced heating of the lining.

Quantitative figures for overall savings, as a percentage of gas input to furnace, for upgrading conventional lining cannot be stated due to the many variables encountered in actual heat treat practices as applied to individual foundry operations. Savings shown in the example calculations, for lining replacements is attributed to radiation loss savings only.

Improving Combustion Efficiency

A Heat Treat Furnace has the following characteristics (from input data sheet);

- Furnace size: 20' x 10' x 8 ft. high.
- Furnace capacity: 20,000 lbs.
- Operating temperature: 1,650° F.
- 5% CO_2 in flue gas.
- Flue gas temperature: 1,650° F.
- Natural gas flow rate: 116 Terms/Hr. or 11,600 cu. ft.
- Furnace physical condition: 1/4" crack visible all around door.

Calculate present combustion and furnace efficiency and probable furnace efficiencies if the furnace was upgraded as follows:

- Install nozzle mix burners with flue/air ratio controls.
- Install furnace pressure controls.
- Install hot gas recuperator for preheating combustion air.
- Repair furnace door and seal cracks.

Example No. 1: Calculate present excess air and available heat.

Excess air through burner system with 5% CO_2 in flue gas (from Figure 3-9) is 130%.

Therefore, available heat to do work, (from Figure 3-10) with 130% excess air and 1,650° F. flue gas temperature, is 20% of 11,600 cu. ft./Hr. of natural gas which is:

11,600 cu. ft/Hr x 0.20 = 2.320 cu. ft/Hr or 2,320,000 Btu/Hr

Example No. 2: Calculate secondary excess air infiltration due to door leakage.

From Figure 3-16A with an average furnace temperature of 1,650° F., the furnace negative pressure due to chimney effect is 0.011" WC per foot of furnace height.

Therefore, total negative pressure is 0.011 x 8 = 0.088" WC.

From Figure 3-16B with a total furnace negative pressure of 0.088, the air infiltration is approximately 280 cubic feet per hour per square inch of crack opening.

Therefore, total crack opening is, based on 28 linear feet of door circumference, 336 inches x 1/4" = 84 sq. inches.

From Figure 3-16A with an average furnace temperature of 1,650° F., approximately 35 Btu is necessary to heat each cubic foot of infiltrated air, therefore, total heat required is:

35 Btu x 84 sq. inches x 280 cu. ft/Hr/Sw. inch = 823,200 Btu/Hr.

<u>Present Combustion Efficiency</u>

From Example 1.	Available heat	= 2,320,000 Btu/hr.
From Example 2.	Heat Lost (Infiltration)	= <u>823,200</u> Btu/hr.
Net Heat Available		= 1,496,800 Btu/hr.

$$\text{Efficiency} = \frac{1,496,800}{11,600,000} \times 100 = 12.9\%$$

<u>Example No. 3</u>: Calculate probable combustion efficiency after installing new burner system and sealing furnace cracks. CO_2 content corrected to 11% and positive pressure maintained in furnace.

Available heat to do work (from Figure 3-10) with 10%.

Excess air is 53% x 11,600,000 Btu/hr = 6,148,000 Btu/hr

Net increase in heat content available is:

6,148,000 Btu/hr - 1,496,800 Btu/hr = 4,651,200 Btu/hr

or 75.65% increase

Based on 5 days per week, 50 weeks per year heat treat operation with heat-up time averaging 6 hours, the yearly energy savings would amount to:

$$\frac{4,651,200 \text{ Btu/hr} \times 5 \times 50 \times 6}{100,000 \text{ Btu/Therm}} = 69,000 \text{ Therms per year.}$$

Combustion Air Preheating

From the preceding examples approximately 5,452,000 Btu/hr (11,600,000 - 6,148,000) is lost through the exhaust stack and radiation losses through the furnace walls. By preheating the combustion air with the use of a hot gas recuperation, the following additional energy savings can be realized.

Example No. 4: With flue gas temperature of 1650° F, calculate the energy savings if combustion air is preheated to 1200° F.

From Figure No. 3-12 the resultant fuel savings will amount to approximately 28%.

Therefore, additional heat saved per hour

$$= 0.28 \times 11{,}600{,}000 \text{ Btu/hr} = 3{,}248{,}000 \text{ Btu/hr}$$

Annual energy savings, using same operating time as stated in example 3, is:

$$\frac{3{,}248{,}000 \text{ Btu/hr} \times 1{,}500 \text{ Hrs.}}{100{,}000 \text{ Btu/Therm}} = 48{,}000 \text{ Therm/yr}$$

Overall Furnace Efficiency

The following table summarizes the possible cost and energy savings by upgrading existing furnace.

TABLE 3-XIV. SUMMARY OF COST AND ENERGY SAVINGS

Item	Btu/hr Saved	ENERGY SAVINGS PERCENT	Annual Gas Savings Gas (Therms)
Furnace Radiation Losses	115,140	70%	4,600
Improve Comb. Efficiency	4,651,000	53%	69,000
Pre-heat Combustion Air	3,248,000	28%	48,000
Total	8,014,140		121,600

$$\text{Overall Energy savings} = \frac{8{,}014{,}140}{11{,}600{,}000} \times 100 = 69\%$$

Note: The foundry industry, in general, is experiencing between 50 to 60% actual Energy Savings by upgrading their present heat treat furnaces. Energy calculations in Section 3 of this study are based on 56% savings.

LADLE HEATING

General

Ladle Heating is a very necessary requirement in any foundry operation. It is a large user of natural gas and probably represents the greatest abuse of gas energy in foundries today. This Section will examine the requirements for upgrading or replacing existing equipment for ladle drying and heating, covering the following:

- Ladle covers
- Burner efficiencies
- Improved insulation

Formulas, calculations, and graphs have been simplified within the scope of the project to reflect constant conditions during the process.

To investigate any process in depth it is essential to establish parameters, calculate the data and plot results on a continuous basis to establish the limits of the operation and equipment and identify any trends.

FIGURE 3-18

OPERATIONAL DATA FACT SHEET

LADLE PREHEAT DATA

LADLE CAP TONS 1.0 HEAT CYCLES/DAY 3

LADLE AREA INSIDE 12 SQ FT. LINING THICKNESS 2.5 ins.

COVERED No TYPE OF LINING Firebrick

INSIDE TEMP 1560 ^{o}F OUTER SHELL TEMP 300 ^{o}F

AMBIENT TEMP N/A ^{o}F

GAS USAGE/HR 550 CU FT. CO_2 READING N/A

COMBUSTION AIR N/A CFM PRESSURE -- WG

PREHEAT CYCLE TIME 1.0 HRS FLUE TEMP -- ^{o}F

REFRACTORY K VALUE 6 RS VALUE 0.33

BLOWER HP N/A RECUPERATOR EFFCY --

FUEL COST/THERM $ N/A ANNUAL USE N/A BTU x 10^6

NUMBER OF UNITS IN USE 1

GRAPHS, TABLES AND CHARTS

Figure 3-19 shows typical relationship of time versus temperature to fuel input for uncovered and covered ladles both with tight fitting and raised covers.

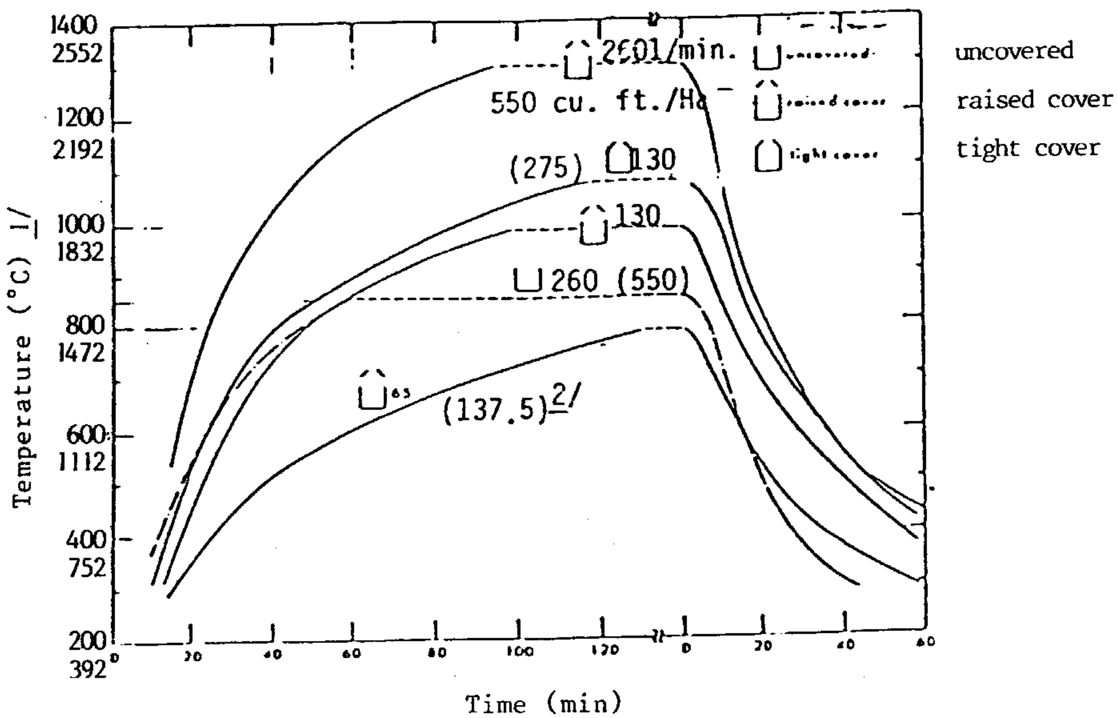


FIGURE NO. 3-19 . EFFECT OF LADLE COVERS

1/ Temperatures both in ^{o}C and ^{o}F at the inside bottom of the ladle.

2/ Figures shown as gas flow rates in liters per min. and cubic feet per hour.

Example of use: Curve is developed for specific ladle size with measured gas flow rates.

Read elapse time from intersection of curve with temperature.

For covered ladle at 275 cu. ft/hour gas flow, the time to attain required temperature 850^{o}C, is approximately 50 minutes.

FIGURE 3-20
HEATING CHARACTERISTICS

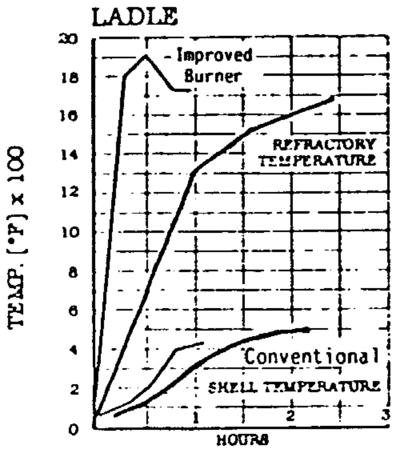
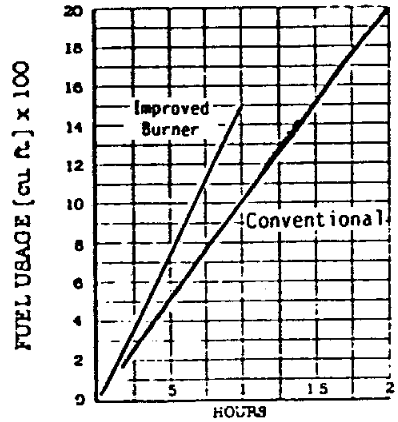


FIGURE 3-21
FUEL CONSUMPTION



Reference: Hotwork Mfg. Inc.

Example of use:

Figure 3-20: Read elapsed time hours at intersection of temperature with approved burner graph line; then,

Figure 3-21: Obtain fuel usage for improved burner by reading up from elapsed hours to intersection with graph line and across to fuel usage.

For example: At temperature requirement of 1300° F, read approximately 0.25 hours (for improved burner) from Figure 3-20.

Transfer hours (0.25) onto Figure 3-21 and read approximately 400 cu. ft. fuel used by improved burner.

TABLE 3-XI. THERMAL PROPERTIES OF CONCRETES

8 — Typical Thermal Properties of Refractory and Insulating Concretes (Mix proportions approx. 1 vol. cement: 3 - 4 vols. aggregate).

Aggregate.	Fired density, lb. per cub. ft.	Heat capacity, B.t.u. per (cub. ft.) (deg. F.)	Thermal conductivity, B.t.u. per (hr./sq. ft.) (deg. F. per in.)	Thermal diffusivity, (sq. ft. per hr.)
Vermiculite	35	9	1.2	0.011
Diatomite	55	14	1.7	0.010
Crushed H.T. insulating brick	85	21	3.2	0.013
Expanded clay	90	22	3.5	0.013
Crushed firebrick	115	29	6	0.017
Molochite	120	31	8	0.021
Sillimanite	135	33	10	0.025
Carborundum	145	40	50	0.103
Calcined bauxite	160	45	12	0.022
Magnesite	160	45	20	0.037
Chrome-magnesite	165	37	8	0.013
Fused magnesia	170	50	24	0.04
Fused alumina	175	52	16	0.026
Bubble alumina	95	22	6	0.023

TABLE 3-XVI. THERMAL CONDUCTIVITY OF CONCRETES

	2100	2400	2600	2800	3000
Maximum Recommended Use Temperature	2100°F (1150°C)	2400°F (1315°C)	2600°F (1425°C)	2800°F (1540°C)	3000°F (1650°C)
Density (PCF)	12-15	18-22	18-22	18-22	18-22
Thermal Conductivity - k (BTU - In./S.F. - °F - Hr.)			Same k values for these compositions.		
Mean Temperature °F: 600°F	0.26	0.29			
800°F	0.36	0.35			
1000°F	0.48	0.41			
1200°F	0.62	0.48			
1400°F	0.77	0.57			
1600°F	0.93	0.67			
1800°F	1.08	0.79	"k" measurements made at Refractories Research Center, Ohio State University.		
2000°F	1.24	0.93			
2200°F	-	1.10			
2400°F	-	1.30			

* Ref. Industrial Insulations Inc.

SAMPLE CALCULATIONS

Ladle Covers:

Heat loss during pre-heat of ladle relates to time in attaining required temperature measured at the inside bottom of the ladle.

Typical burner sizes for average ladle capacities of 1 ton (iron) is 1.0×10^6 Btu/hr. Therefore energy savings for any capacity ladle can be prorated based on pre-heat time for any size burner.

Example:

Burner size 1" (1.0×10^6Btu/hr) shows a gas flow rate of 275 cu.ft./hr.

The elapsed time to attain 850°C (1560° F) with the tight-cover ladle, is approximately 50 minutes, reference Figure 3-19.

Thus gas usage = $\frac{50}{60} \times 275{,}000 = 0.230 \times 10^6$ Btu.

The elapsed time to attain 850° C (1560° F) with a raised cover ladle utilizing gas flow rate of 275 cu.ft./hr, is approximately 50 minutes, reference Figure 3-19.

Thus gas usage = $\frac{60}{60} \times 275{,}000 = 0.275 \times 10^6$ Btu

The elapsed time to attain 850° C (1560° F) with an open ladle utilizing gas flow rate of 550 cu.ft./hr is approximately 60 minutes, reference Figure 3-20.

Thus gas usage = $\frac{60}{60} \times 55{,}000 = 0.55 \times 10^6$ Btu

Relative savings for the alternate arrangements is:

Item	Btu's	Change in energy
Uncovered ladle	550,000	-0-
Raised cover ladle	275,000	- 50.0%
Tight cover ladle	230,000	- 58.0%

In quantitative terms the covered ladle (tight cover) results in gas usage reduction of:

$$550{,}000 \times 0.58 = 320{,}000 \text{ Btu/hr}$$

It should be noted that the example is worked for one ladle only whereas generally more than one ladle is in use daily. Also size of ladle and therefore burner size will have impact on total possible savings.

COMBUSTION SYSTEMS

High efficiency burners reduce drying and preheating time which translates into increased ladle utilization and energy reduction.

Comparison between a conventional burner (high intensity) and a high efficiency burner is shown in Figure 3-20 and Figure 3-21.

Example: Time required to raise ladle refractory to 1300° F is 1 hour, using conventional burner.

Indicated time for improved burner with high efficiency characteristics, is shown on Figure 3-20 to be approximately 0.25 hours. With fuel usage of 1,000 cu. ft. and 400 cu. ft. respectively as indicated on Figure 3-22.

Thus efficiency improvement is calculated from

$$\frac{\text{Fuel usage reduction} \times 100}{\text{Original fuel usage}} = \text{percent}$$

$$\text{Therefore: } \frac{(1{,}000 - 400) \times 100}{1{,}000} = 60.0\%$$

Equivalent energy reduction for ladle preheating in previous example using 230,000 Btu/hr, the gas usage reduction is:

$$230{,}000 \times 0.60 = 138{,}000 \text{ Btu/hr.}$$

INSULATION

Ladle insulation and covers increase heating efficiency which leads to quicker heating and thus less time for losing energy by conduction and radiation through the ladle walls. Improved wall insulation saves energy in two ways, first by reduction in pre-heat gas requirements and second by minimizing the metal temperature loss during the pour, thus lowering the initial superheat required by the melter and extending the usable pouring period of the ladle with the possibility of reducing scrap castings by pouring less cold metal.

Example of energy savings by installing 1/2 inch insulation between the 2 inch refractory and the shell. The heat lost during ladle preheating is to be calculated and compared to lining without insulation.

Area of lining 30" dia. x 30" deep = 12 sq. ft.

Heat loss through conventional lining material is calculated from

$$Q = \frac{t_1 - t_2}{R_1 + R_2} = \text{Btu/Sq.Ft/hr}$$

$$\text{Where } R = \frac{\text{Thickness of Lining}}{\text{"K" value}}$$

t_1 = hot face temperature (1300° F)

t_2 = cold face temperature (200° F)

K = thermal conductivity of lining material from Figure 4 and Figure 5

$$\text{Thus Qa (no insulation)} = \frac{(1300 - 200)}{R_1} \text{ 12 sq.ft.}$$

$$R_1 \text{ (high alumina cement)} = \frac{2.5 \text{ inches}}{K} = \frac{2.5}{6} = 0.42$$

$$Q = \frac{1100 \times 12}{0.42} = 31{,}400 \text{ Btu/hr}$$

$$\text{Qb (with insulation)} = \frac{(1300 - 200)\ 12}{R_1 + R_2}$$

$$R_1 = \frac{2 \text{ inches}}{6} = 0.333$$

$$R_2 \text{ (ceramic fiber)} = \frac{0.5}{K} = \frac{0.5}{0.29} = 1.72$$

Note: Ceramic fiber layer assumed to have a mean temperature below 600° F.

$$Qb = \frac{1100 \times 12}{0.333 + 1.72} = 6{,}400 \text{ Btu/hr}$$

Reduction in heat loss = 31,400 - 6,400 = 25,000 Btu/hr

Equivalent to 79.6% savings in energy.

From previous example, net reduction in energy usage is:

31,400 Btu/hr x 0.796 = 25,000 Btu/hr

SUMMARY (PROBABLE ENERGY SAVINGS)

The following table summarizes present and probable energy requirements for ladle heating as determined in sample calculations if all the improvements are carried out.

TABLE 3-XVII. PROBABLE SAVINGS

ITEM	BTU/HR SAVED	%SAVINGS	ANNUAL GAS THERMS
Covers	320,000	58.0	1,233
Combustion System	138,000	60.0	533
Insulation	25,000	79.6	96
EQUIPMENT TOTAL	483,000	--	1,862

Actual overall energy saving between 50% and 60% is considered to be practical for the majority of ladle heating operations. Additional savings can be realized if ladle heater utilization is reduced to 15% of the typical 8 hour shift period.

C. COKE FUEL MELTING - CUPOLA

GENERAL

Methods of melting to be analyzed in this section are:

- Lined Cold Blast Cupola
- Lined Cupola With 500° F Hot Blast
- Water Cooled Cupola With 1,000° F Hot Blast
- Divided Blast Cupola, Cold Blast
- Lined Cupola, Cold Blast With 2-4% Oxygen Enrichment

COKE USAGE

The conventional cupola is a vertical shaft type furnace with a refractory lining and equipped with a windbox and tuyeres for the admission of air. The sequential material charges, through the stack of the cupola, comprise alternate layers of metallics and coke with some fluxes added. The descending fuel replaces that burned from the original coke bed and maintains the height of this bed.

COKE BED CALCULATIONS

Example

Recommended coke bed height above the tuyeres is;

10.5 x sq. root of blast pressure (ounces) + 6*

Therefore if windbox pressure = 16 ounces

Bed coke height = $(10.5 \times \sqrt{16}) + 6 = 48"$

Thus the volume of bed coke required per melt campaign is obtainable by reference to Table 3-XVIII. Consider above example and determine weight of coke required in initial bed as follows:

Read Table 3-XVIII, for volume at 16 onz. pressure = 38.5 cu. ft., therefore at 30 lbs/cu. ft., weight of coke = <u>1155 lbs.</u>

Additional coke may be required to be added to maintain bed height during initial melt period, to obtain full burning of the bed prior to the first charge of metal, and for starting the blast. Additional coke to fill the hearth up to tuyere level, must be made based on specific cupola design. Total energy required to operate the cupola, including bed coke and electric power, is to be calculated as shown on the work sheet as follows:

*6 is a suggested factor which may have to vary for a specific cupola.

STANDARD CALCULATION FORMAT FOR CUPOLA ENERGY DATA

Standard 48" Lined, Cold-Blast Cupola. (Desired melt rate 9.0 TPH)

Melt rate TPH. 9.0 X 2000 18,000 LBS/HR.

Metal to Coke ratio 10:1 , Coke charged/hr 1,800 lbs.

CFM air Reqd. 4,100 @ Blast Pressure 18 ONZ

Fan HP 50.0

Skip Loader 7.5

Dust Collector 55.0

Misc. Power 5.0

Equivalent BTU/HR $\frac{117.5 \times .746 \times 3412}{1.73}$ = 172,878

Coke Charged/HR . . . . . . 1800 LBS/HR

Bed Coke x 1/8 225

Equivalent BTU/HR 2,025 x 12,500 = 25,312,500

TOTAL BTU/HR = 25,713,410

AVERAGE BTU/TON OF METAL CHARGED = 2,831,700

OPERATION OF SPECIAL CUPOLAS

Comparison of current cupola operation with alternate systems, hot blast type, divided blast or oxygen enriched blast, can be made by reference to the model energy chart graphs at specific melt rate requirements.

It assumed that the cupola melt rate, in all cases, is based on conventional practice prior to improvements.

TABLE 3-XVIII. BED COKE REQUIREMENTS

NORMAL WINDBOX PRESSURE (OZ)	BED COKE ABOVE TUYERES (INCHES)	MELT DIAMETER (INCHES)	ZONE AREA (SGINS)	VOLUME COKE (CU.FT.)
7	28-34	18	254	5.0
12	36-42	23	415	10.0
14	40-46	32	804	21.4
16	42-48	42	1,385	38.5
18	45-51	48	1,809	53.4
20	47-53	72	4,071	124.9

Assumption:
Density of Cupola Coke = 30 lbs/cu.ft.

TABLE 3-XIX. CUPOLA OPERATING CHARACTERISTICS

IRON TO COKE RATIO	COKE PER TON OF MELT LB	MELTING RATE TONS PER HOUR	METAL TEMPERATURE °F	APPROXIMATE THERMAL EFF., %
12 to 1	167	16.0	2,656	46.7
11 to 1	182	15.2	2,672	43.0
10 to 1	200	14.2	2,686	39.5
9 to 1	222	13.1	2,706	36.0
8 to 1	250	12.0	2,730	32.0
7 to 1	286	10.9	2,762	28.4
6 to 1	333	9.8	2,798	27.0

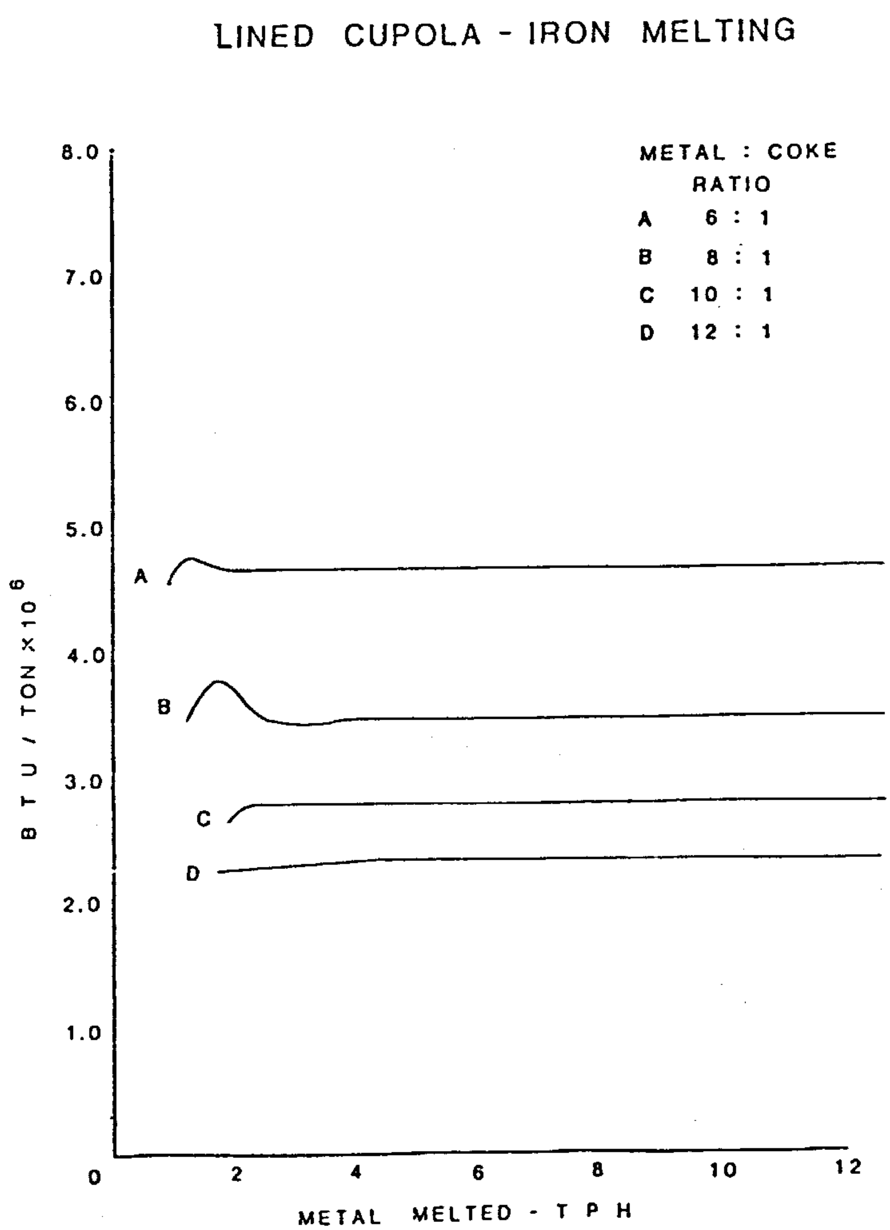


FIGURE 3-22

CUPOLA OPERATING CHARACTERISTICS - LINED CUPOLA - IRON MELTING

MELTING GRAY IRON

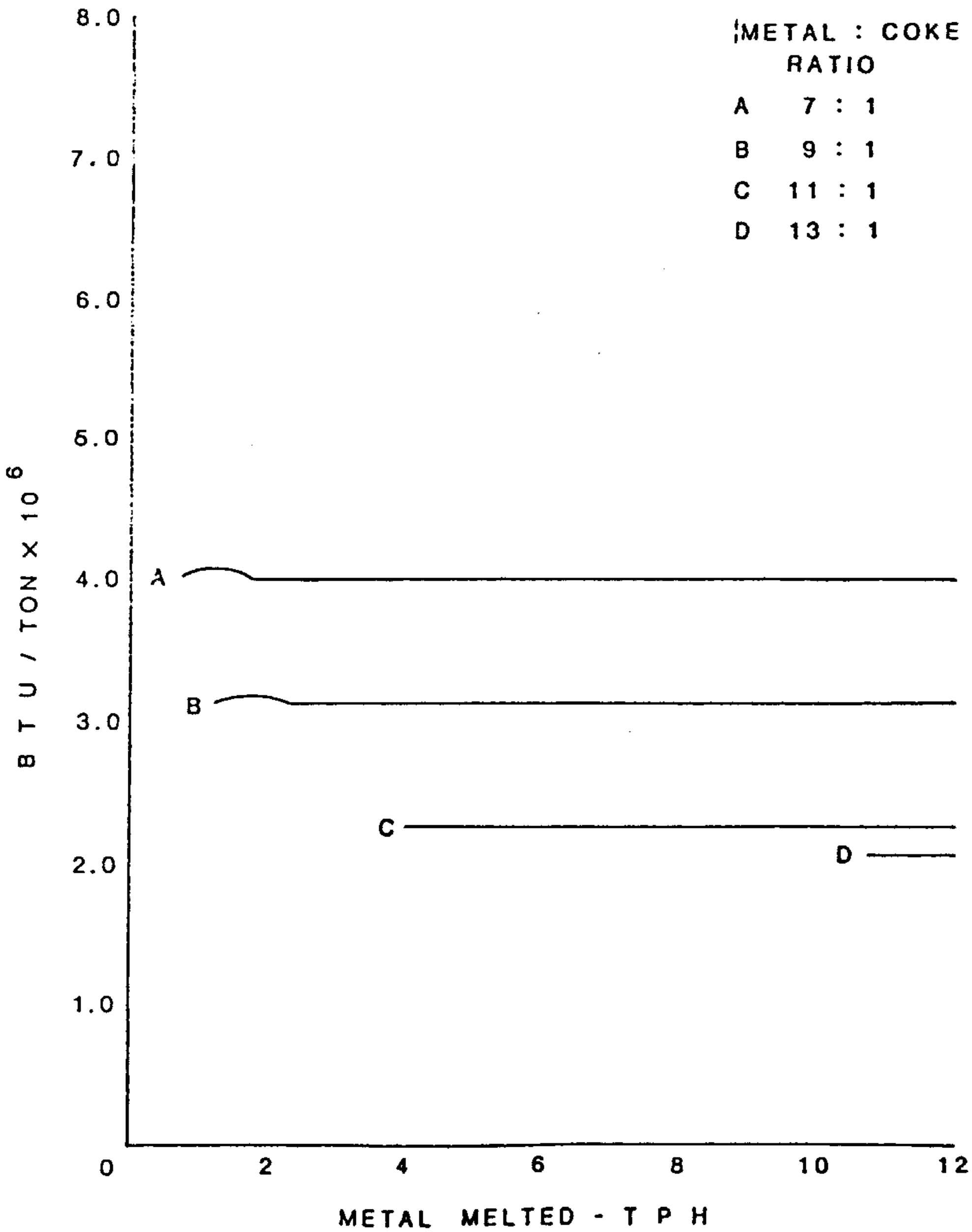


FIGURE 3-23

CUPOLA OPERATING CHARACTERISTICS - LINED CUPOLA, 500°F HOT BLAST

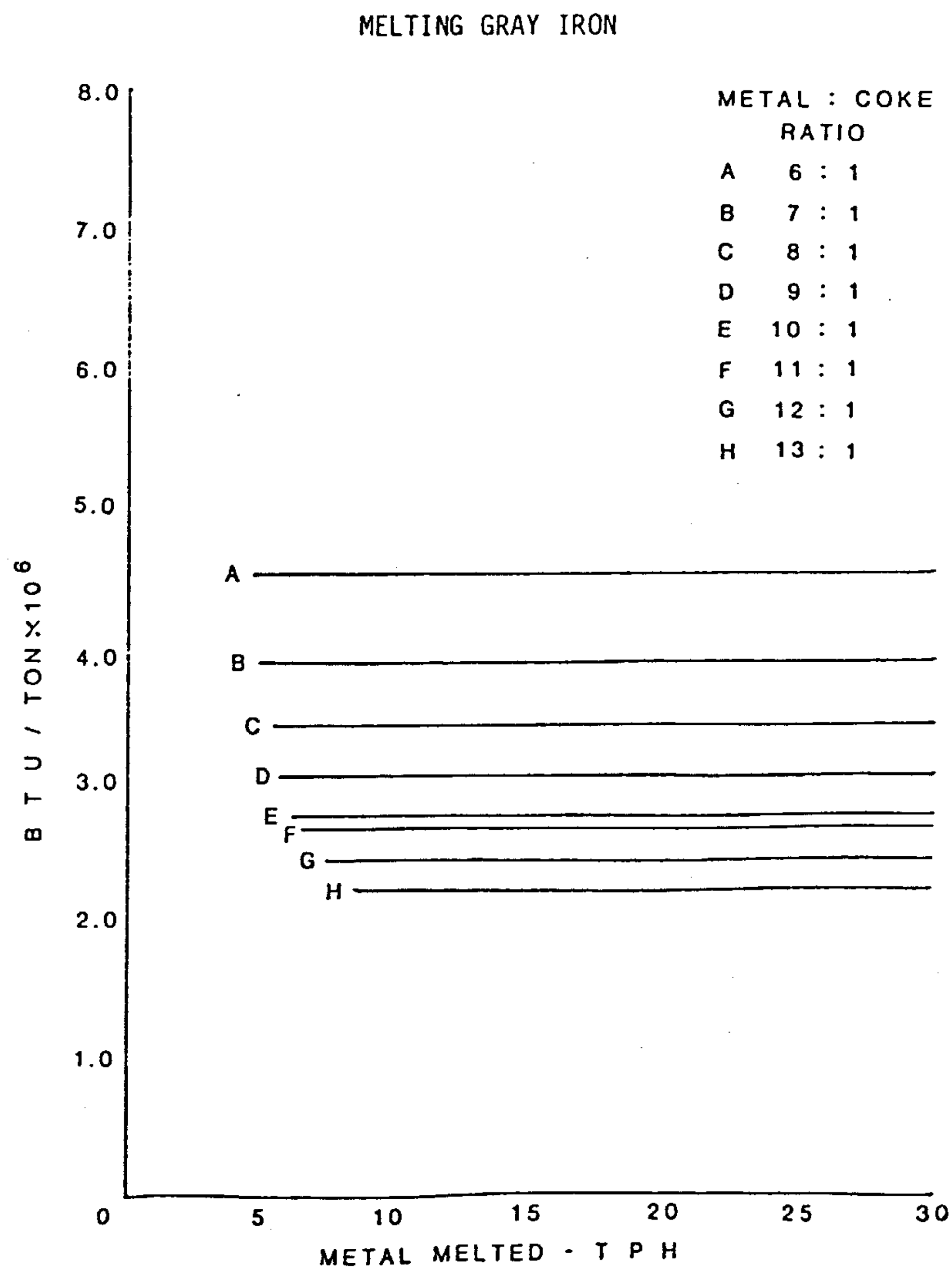


FIGURE 3-24

CUPOLA OPERATING CHARACTERISTICS - LININGLESS 1000°F HOT BLAST CUPOLA

MELTING GRAY IRON

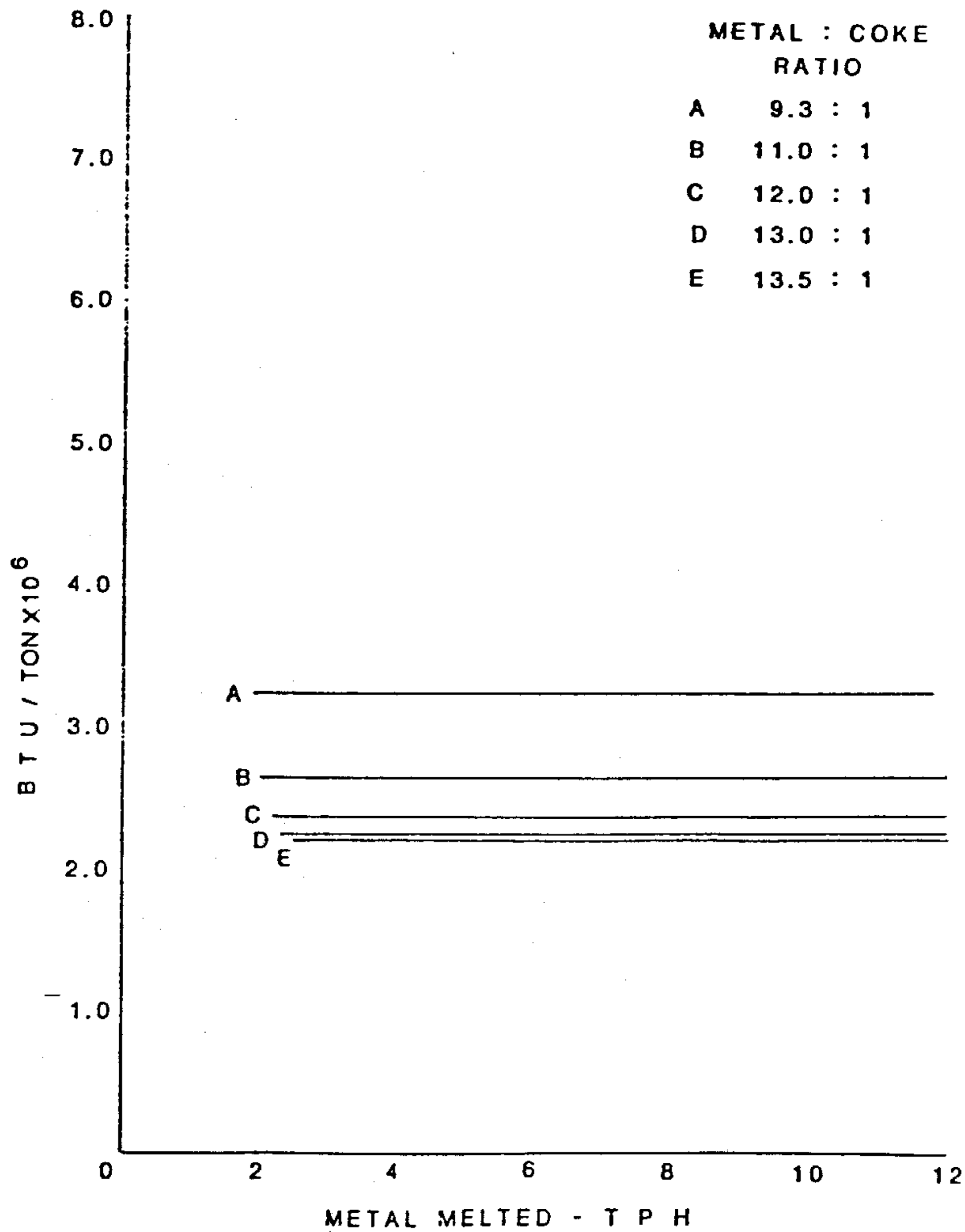


FIGURE 3-25

CUPOLA OPERATING CHARACTERISTICS - DIVIDED-BLAST CUPOLA

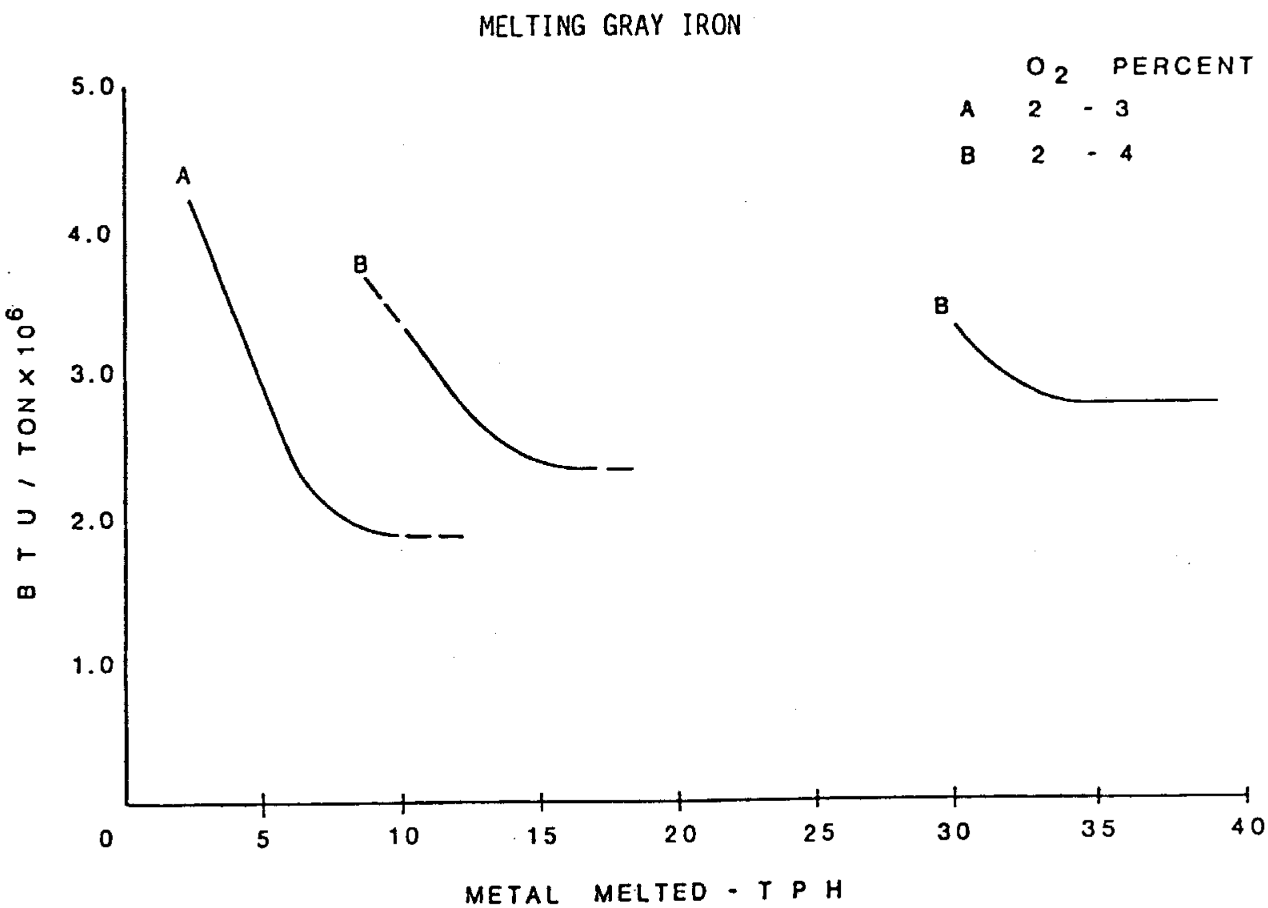


FIGURE 3-26

CUPOLA OPERATING CHARACTERISTICS
LINED COLD BLAST CUPOLA WITH OXYGEN ENRICHED BLAST

RELATIVE MELT RATE/HOUR FOR 1,000°F
HOT BLAST LINING LESS WATER-COOLED CUPOLA

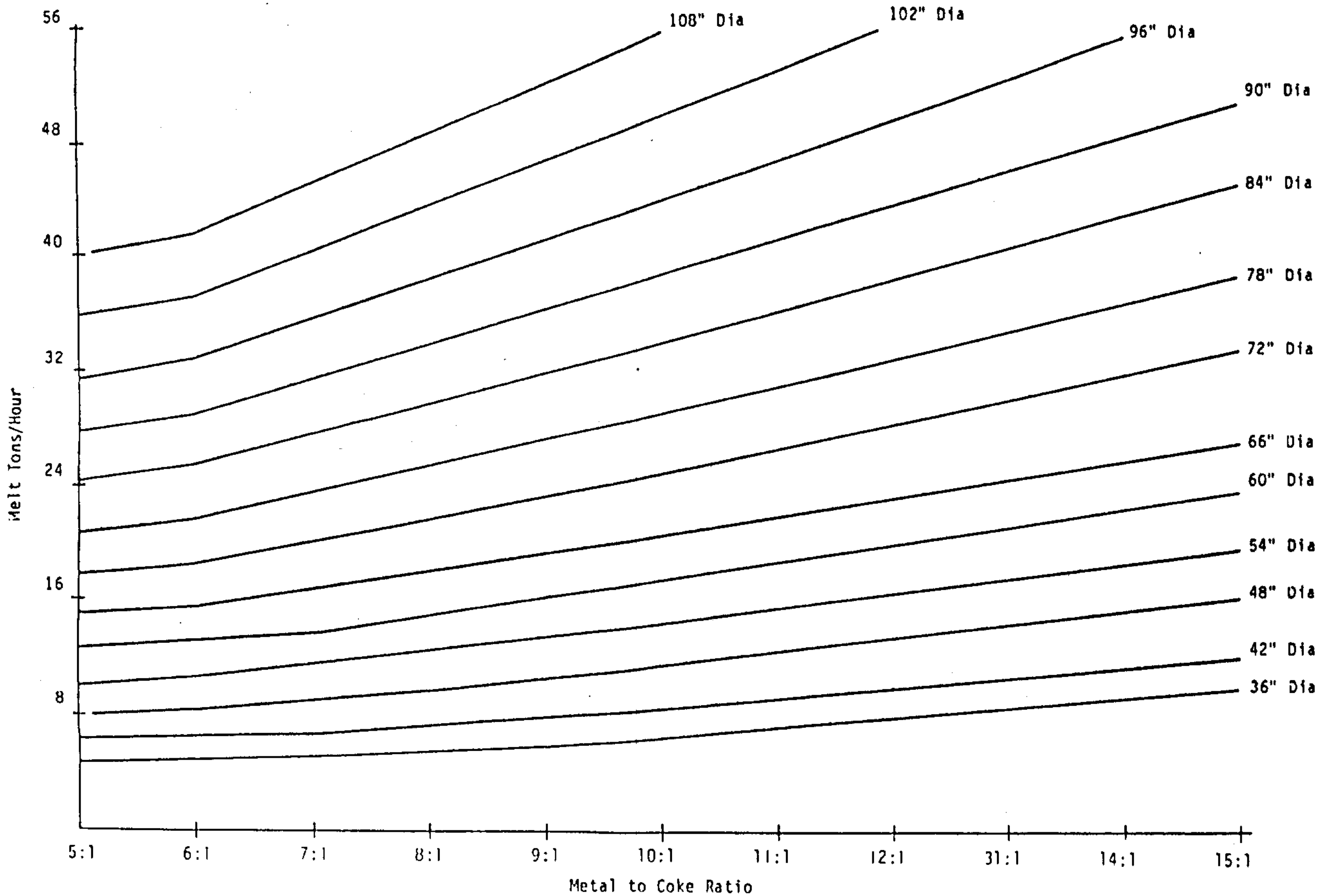


FIGURE 3-27

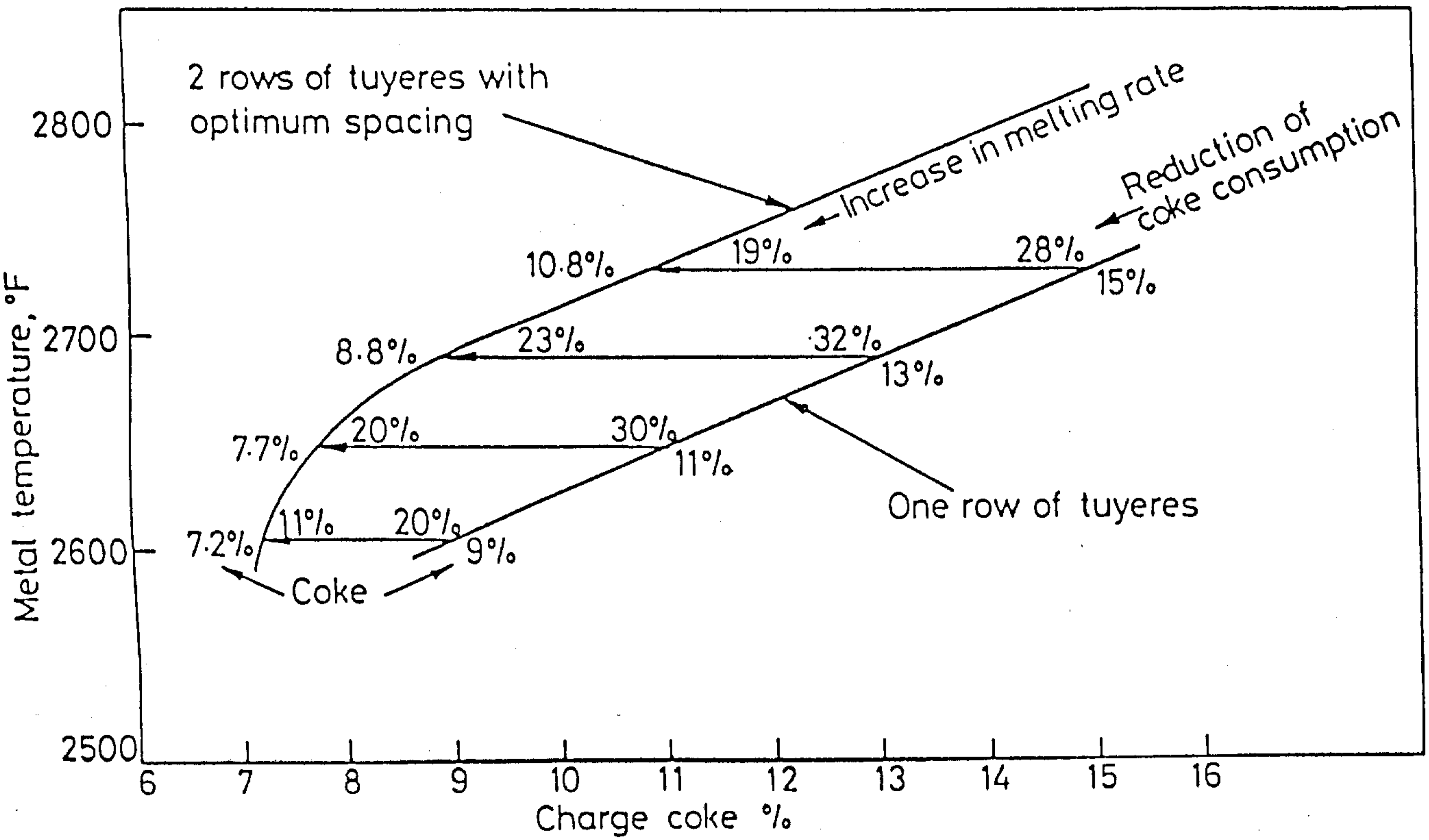


Figure 3-28

Reduction of charge coke consumption and increase in melting rate by operating cupola with two rows of tuyeres with divided-blast supply (Blast rate 1600 ft^3/min)

COKE TO METAL RATIO

The range of sizes and operating recommendations for conventional cupolas has been developed over a long period of time resulting in fairly standard data (see Table 3-XIX). Ratio of metal weight to coke charged, excluding the bed coke, determines the melt rate and/or temperature of iron as it leaves the cupola with conventional designed cupolas. Higher tapping temperatures involve a penalty in coke usage and melt rate.

Example

If metal is to be tapped from a cupola at 2,762° F, calculate the energy (coke) penalty compared to tap temperature of 2,686° F. From Table X-XIX, a cupola producing 10.9 tons per hour with iron to coke ratio of 7:1 for 2,762° F tap temperature, results in approximate thermal efficiency of 28.4% at 2,686° F.; the cupola would produce 14.2 tons/hour with iron to coke ratio of 10:1 and approximate thermal efficiency of 39.5%.

Thus at 7:1 ratio, coke usage = 286 lbs/ton melted

10:1 ratio coke usage = 200 lbs/ton melted

Reduction = 86 lbs/ton melted

∴ Penalty for 76° F super heat is equivalent to:

$86 \times 12{,}500$ BTU/lb = 1.075×10^6 BTU/ton melted

Annual energy reduction based on 15,000 tons per year of metal melted

$= 1.075 \times 10^6 \times 15{,}000 = \underline{16{,}125 \times 10^6 \text{ BTU}}$

$$\text{Energy reduction} = \frac{86}{286} = 30.0\%$$

Thermal efficiency improvement = 39.5 = 28.4 = 11.1%

Note- In above example the coke bed height in each case is the same and does not effect the melting energy difference.

Tap temperature reduction may be impractical without other operational improvements such as insulation of launders, pouring ladles, etc. Control of production scheduling is required to minimize holding periods or delays prior to pour off; also, redesign of gating to enable lower casting pouring temperatures is another requirement.

SPECIAL CUPOLA MELTING CONDITIONS

To obtain increased melting or higher temperature and more efficient coke usage, refinements to the standard cupola are available.

Blast conditioning, through utilization of recuperative hot blast, can be provided using the waste heat from the cupola exhaust.

HOT BLAST SYSTEM

Model energy usage in BTU/ton of iron melted can be determined by reference to specific charts and by projecting a point on the graph, at known metal to coke ratio, from desired melt rate in tons per hour. (Figure 3-23 - 24)

Value determined from the graph can be compared to proposed operation under new conditions of operation, by calculation of actual energy usage difference for requirements, as per following example.

Example

In the previous example, the metal to coke ratio in a conventional cupola is 10:1. From Figure 3-22, graph line C, the energy required to melt is 2.85×10^6 BTU/ton. (Includes melt coke, bed coke and electrical energy.)

From Figure 3-27, for conditions of $1{,}000^o$ F hot blast, a similar size 48" diameter cupola is indicated to be capable of melting 14.2 tons/hr. at 13:1 metal to coke ratio.

Thus reading energy required for 1000^o F hot blast cupola at 13:1 metal to coke ratio, from Figure 3-25 is:

Energy required = 2.20×10^6 BTU/ton

Reduction in energy/ton = $(2.85 - 2.20)\ 10^6$ BTU/ton = 650,000 BTU/ton

Which is equivalent to $\frac{0.65}{2.85}$ = 22.8% improvement

$\therefore$ Annual energy reduction based on 15,000 tons of metal melted

per year = $\frac{650{,}000 \text{ Btu/ton melted}}{12{,}500 \text{ BTU/lb.}}$ = 52 lbs coke/ton

DIVIDED BLAST CUPOLA

Provision of two rows of tuyeres enables higher metal tapping temperatures to be obtained for a given consumption of coke, or reduction of 20 to 30 percent coke with increased melt rate of 11 to 23 percent with a given blast rate and constant tapping temperature. Comparison of thermal balances for conventional (one row of tuyeres vs. divided blast operation) is as follows:

Item	Conventional	Divided
Coke charge %	12.0	12.0
Metal temp.°F	2655	2755
Top gas composition CO_2 %	11.9	13.1
Top gas composition CO %	15.0	13.0
Combustion ratio $\frac{CO_2}{CO_2+CO}$ X 100	44.2	49.8
Top gas temp. °F	860	970

Utilization of Heat Supplied

Sensible heat in metal at Top temp. (thermal efficiency)	%	34.7	35.7
Latent heat in top gas	%	38.9	35.0
Sensible heat in top gas	%	12.8	15.1
Other losses	%	13.6	14.2
TOTAL		100.00	100.00

Example

Show reduction of charge coke consumption and increase in melting rate by operating a cupola with two rows of tuyeres at a blast rate of 1,600 cu. ft/min, compared to the cupola operating under previous example conditions. At 13:1 metal to coke ratio, the charge coke is 7.7% addition. Read Figure 3-28 for reduction of coke with two rows of tuyeres (divided blast) at 2,686^{0} F metal temperature and 7.7% charge coke.

∴ From graph line (Figure 3-28) for 2 rows of tuyeres, the reduction of coke consumption = 30%

Thus coke savings for divided blast cupola operation,

= 2,000 x 0.077 x 0.3 = 36.2 lbs/ton of melt

@ 12,5000 BTU/lb, energy saved per ton of melt = 46.2 x 12,500 = 577,500 BTU

Total energy requirements for cupola from previous example is approximately 2.20 x 10^6 BTU/ton melted at 13:1 metal to coke ratio.

Revised energy requirement: divided blast cupola, per ton
$= 2.20 \times 10^6 - 577,500 = 1.62 \times 10^6$ BTU

By calculation, the new metal to coke ratio is equivalent to energy required at 15.8:1 metal to coke ratio or approximately 126 lbs of coke per ton of melt.

$\therefore$ Annual energy reduction based on 15,000 tons of melt required per year $= 577,500 \times 15,000 = 8662.5 \times 10^6$ BTU

$$\text{Percent energy reduction} = \frac{577,500}{2.20 \times 10^6} = 26.2\%$$

OXYGEN ENRICHED BLAST SYSTEM

A minimum production rate of 15 tons/day and 3 days per week is generally needed to justify the use of oxygen to gain production increase. Also no major reduction in coke usage occurs above 10 tons per hour melt rate with 2 - 3% O_2 enrichment. Savings at lower production rates are obtained as follows:

Example

Increased melting rate and/or tap temperature can be obtained by oxygen enrichment of 2 - 3%.

The total energy required can be read from graph 'A' Figure 3-26 for production under 10 tons/hour.

Thus energy at 9 tons/hour metal melted $= 1.85 \times 10^6$ BTU/ton

Energy reduction compared to say a divided blast cupola (ref. Figure 3-25) with metal to coke ratio of 13.5:1 (graph "E")

$$2.20 \times 10^6 - 1.85 \times 10^6 = 350,000 \text{ BTU/ton}$$

$$\text{Percent savings} = \frac{350,000}{2.20 \times 10^6} = 16\%$$

$$\text{Cost reduction based on reduction of coke} = \frac{350,000}{12,500} \text{ BTU/lb}$$

OVERALL ENERGY SAVINGS

The following table summarizes the possible cost and energy savings by improvements to the cupola operation.

TABLE 3-XIX.
SUMMARY OF COST AND ENERGY SAVINGS

ITEM	BTU/TON SAVED	ENERGY % IMPROVEMENT	ANNUAL COKE THERMS
Tap Temp. Reduction	1,075,000	30.0%	161,250
Hot Blast System	650,000	22.8%	97,500
Divided Blast System	577,000	26.2%	86,625
Oxygen Enrichment (Not Applicable)		-	-
TOTAL	2,302,000		345,375

ECONOMIC EVALUATION

The order of magnitude cost, to implement all improvements for the sample cupola considered, is used to emphasize the viability of large capital expenditures for energy conservation measures. The payback is further improved, if full tax credits are accounted for and adjustments made for impact of future energy cost.

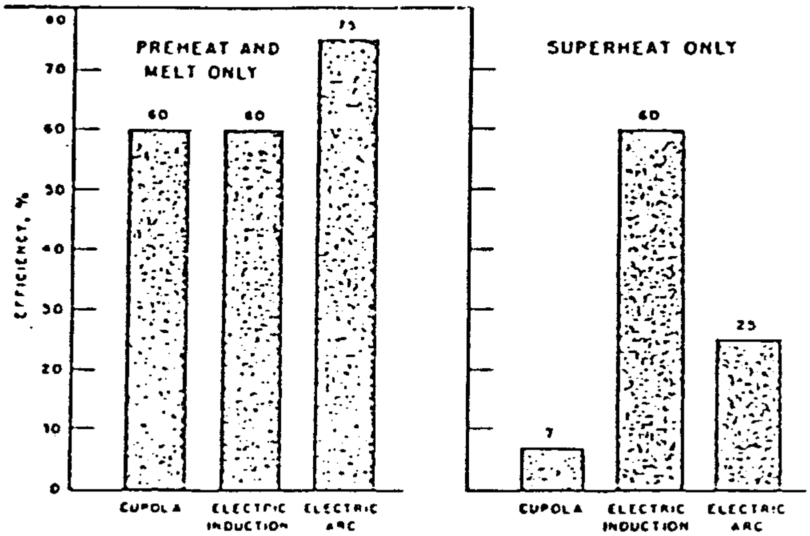


FIGURE 3-29. MELTING EFFICIENCIES

The following TABLE compares the three practical melting methods with respect to energy economics.

TABLE 3-XXI. MELTING METHOD COMPARISON

ITEM	CUPOLA	ELECT. INDUCTION	ELECT. ARC.
Cost to preheat	\$ 8.01	\$ 13.99	\$ 11.19
Cost to melt	2.71	4.73	3.79
Cost to superheat	13.74	2.80	6.72
TOTAL	\$ 24.46	\$ 21.52	\$ 21.70
BTU's required x 10^6	3.65	1.84	1.85

Example

Cost to pre-heat one ton of metal by cupola to melt temperature;

$$\text{Btu required} = \frac{35.8 \text{ Btu/lb} \times 2000 \text{ lbs.}}{60\% \text{ Efficiency}} = \frac{0.72 \times 10^6}{0.60} = 1.196 \times 10^6$$

On the basis of this analysis, the electric induction furnace is more energy efficient. However, the analysis can be applied to any combination of melting methods to obtain the most energy cost effective results (See Figure 3-29).

COKE VS. ELECTRICITY

COMPARATIVE ANALYSIS

Determining the best method involves consideration of a complex interrelationship of specific foundry needs, relative to furnace operation. Energy for melting is only one aspect and not necessarily the primary factor, however, this analysis deals with differences in costs of melting due to energy only.

Based on calculated cost of energy developed elsewhere in this study, the cost of potential heat by alternate methods is summarized as follows:

TABLE 3-XV.
COST SUMMARY - COKE AND ELECTRICITY

Item	Foundry Coke	Electricity (Ave.)
Cost of Energy	$167.50/net ton *	$ 0.0400/KW *
Potential Heat Content	12500 Btu/lb.	3415 Btu/KWH

* representative values

Energy for pre-heating, melting and superheating 1 ton of cast iron to 2,700o F.

552 Btu/lb x 2000 = 1,100,000 Btu/ton

Percent of energy requirement for each phase of the melting cycle is as follows:

		Btu/lb.
Pre-heat to melt temp.	552 Btu/lb x 65%	= 358.8
Melt to liquid state	552 Btu/lb x 22%	= 121.4
Super heat to 2,700° F	552 Btu/lb x 1.3%	= 71.8

For melting efficiencies of different types of equipment used for melting cast iron (see Figure 3-29).

D. GAS-FIRED CHARGE PREHEATING

GENERAL

Furnace charge preheating, up to 1000° F for iron or steel, results in energy and cost reductions of up to 25%.

This section deals with charge preheating by:

- Gas-fired burner units.
- Oxygen assisted burners.

Diagrams and tables indicate typical data and performance for equipment commercially available. Similar information should be reviewed from alternate sources prior to actual energy audit work being carried out.

Example

Required: Scrap preheat temperature of 1,000° F for batches of one ton size to be charged to an electric melting unit, operating 8 hours per day, 240 days per year at annual rate of say 3,000 tons of gray iron.

Increased melt production percentage is obtained by reference to Figure 3-31, reading for 'iron' at 1,000° F scrap temperature.

@ 1,000° F, resulting increase = 30%

Equivalent Energy Requirements:

Natural Gas-Fired Unit:

@ 1,000° F = 600 cu. ft/ton = 600,000 Btu (from Table 3-XXII).

Electrical Energy Usage Reduction

@ 1,000° F = 117 kW/ton (from Table 3-XXII).

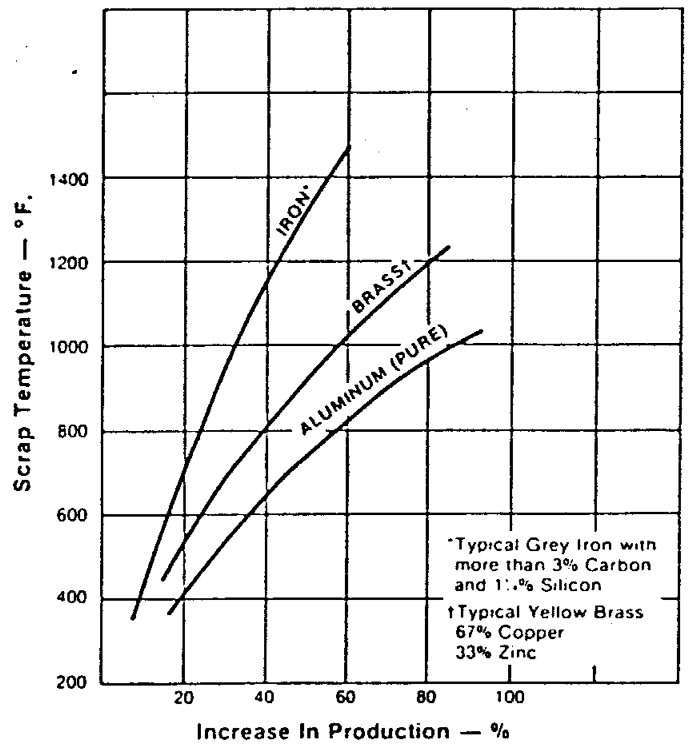


FIGURE 3-31. INCREASED MELT PRODUCTION

TABLE 3-XXII.

Furnace Charge Preheating Energy Comparison for Arc and Induction Melting of Iron, Aluminum and Brass

Efficiency Basis: Induction Furnace @ 70%/Fuel (Gas, Propane, Oil @ 47% to 93%, depending on Temperature).

Preheat Temp. ° F.	KW Usage per Ton Cold Melt			Venetta Usage per Ton/CF Natural Gas @ 1000 BTU/Cu. Ft.			Venetta Usage per Ton/Gal. Propane @ 91,735 BTU/Gal.			Venetta Usage per Ton/Gal. #1 or #2 Fuel Oil @ 138,000 BTU/Gal.		
	Iron	Alum	Brass	Iron	Alum	Brass	Iron	Alum	Brass	Iron	Alum	Brass
500	59	101	44	150	256	105	1.64	2.8	1.14	1.1	1.9	.8
600	70	121	53	216	365	151	2.4	4.0	1.65	1.6	2.6	1.1
700	82	141	62	276	469	193	3.0	5.0	2.1	2.0	3.4	1.4
800	94	161	70	372	640	261	4.1	7.0	2.8	2.7	4.6	1.9
900	106	181	79	480	808	332	5.2	8.8	3.6	3.5	5.9	2.4
1000	117	201	89	600	1012	417	6.5	11.0	4.5	4.3	7.3	3.0
1100	129			792			8.6			5.7		
1200	141			1008			11.0			7.3		
1300	152			1320			14.4			9.6		
1400	164			1680			18.3			12.2		

OXYGEN-FUEL ASSISTED MELTING

Oxy-fuel assisted melting involves supplying additional heat energy during melt down by introducing oxygen with the fuel to supplement or replace the electrical power input to the furnace. Oxy-fuel assisted melting practice has been applied successfully to most nonferrous and ferrous metals with the exception of brass which exhibits high zinc loss. Suitable stoichiometric firing rates are chosen for each metal to minimize oxidation.

> Note: Wellman Alloys Limited of England used oxy-fuel (propane) burner - melting rate increased by 80% - energy savings in excess of 15%.

Example

Data based on various induction furnaces incorporating oxy-fuel indicates average of 26% improvement in power input, reference Table 3-XXIII.

TABLE 3-XXIII. OXY-FUEL ASSISTED MELTING IN INDUCTION FURNACES

Data Obtained From Various Induction Furnaces Incorporating Oxy-Fuel						Melt Down Time Tap to Tap, Min.			Furnace Electrical Power Input, kwhr/ton.			Melting Rates, ton/hr		
Case No.	Furnace Capacity Ton (kg)	Furnace Rating kw	Material Melted	Fuel	Btu/ton × 10⁶ (kwh/ton)	Normal	Assisted	Improvement, %	Normal	Assisted	Improvement, %	Normal	Assisted	Improvement, %
1	.3 (305)	200	Ductile Iron	Propane	.775 (227)	73	51	30	897	626	30	.246	.354	44
2	.5 (509)	150	Ni Cr Alloy	Propane	.60 (176)	150	95	36	1040	720	31	.20	.318	59
3	1.0 (1018)	300	Carbon Steel	Propane	.3175 (93)	150	105	30	815	680	17	.42	.60	43
4*	1.0 (1018)	300	Ni Cr Alloy	Propane	.625 (183)	184	97	47	863	500	42	.325	.612	88
5	1.0 (1018)	600	Ni Cr Alloy	Butane	.592 (173)	90	60	33	733	630	14	.68	.89	31
6	2.0 (2036)	800	Alloy Steel	Nat. Gas	.503 (147)	175	135	23	778	610	22	.67	1.0	49
7	3.0 (3054)	800	Gray Iron	Propane	.730 (214)	190	125	34	770	525	32	.632	.976	54
8	3.0 (3054)	800	Gray Iron	Propane	.297 (87)	95	77	38	580	471	19	.840	1.364	62
*Case 4: Figures and Results are for Flat-Bath only. Courtesy Wellman Alloys Ltd., Amblecote, Stourbridge, West Midlands, England.						Average Improvement		34.5	Average Improvement		26	Average Improvement		48.5

Extracted from Foundry M & T MPS - March 1978
by J. Allread / Grede Foundries, Milwaukee

SECTION 4

ENERGY AUDIT FORMS

A. ENERGY USE TABLES AND PRODUCTION STATISTICS

ELECTRICAL POWER USAGE

BILLING PERIOD	ENERGY KWH	BILLING DEMAND	POWER FACTOR	ENERGY CHARGE	FUEL ADJUSTMENT* CHARGE	DEMAND CHARGE	GROSS BILL	NET BILL
JANUARY								
FEBRUARY								
MARCH								
APRIL								
MAY								
JUNE								
JULY								
AUGUST								
SEPTEMBER								
OCTOBER								
NOVEMBER								
DECEMBER								
TOTALS								

AVERAGE POWER COST $\dfrac{\$\underline{\hspace{4cm}}}{\text{KWH}} = \$\underline{\hspace{2.5cm}}/\text{KWH}$

REMARKS:

FORM 4-1

ANNUAL GAS CONSUMPTION

PERIOD	THERMS	BTU X 10^6	COST
TOTALS			

HEAT CONTENT OF GAS = ________ BTU/CU FT (FROM BILL)

100,000 BTU = 1 THERM

COST OF GAS = $\frac{\$\_\_\_\_\_\_\_\_}{\text{THERMS}}$ = $________ PER THERM

REMARKS:

FORM 4-2

ANNUAL COKE CONSUMPTION

PERIOD	TONS	BTU X 10^6	COST
TOTALS			

AVERAGE COST OF COKE = $\$\frac{\rule{4cm}{0.4pt}}{\text{TONS}}$ = \$____________ PER TON

1 LB. OF COKE = 12,500 BTU

REMARKS:

FORM 4-3

ANNUAL OIL CONSUMPTION

PERIOD	GALLONS	BTU X 10^6	COST
TOTALS			

AVERAGE COST OF OIL = $\frac{\$\_\_\_\_\_\_\_\_\_\_}{\text{GALLONS}}$ = \$__________ PER GALLON

REMARKS:

FORM 4-4

ANNUAL PROPANE CONSUMPTION

PERIOD	GALLONS	BTU X 10^6	COST
TOTALS			

REMARKS:

FORM 4-5

ANNUAL PRODUCTION

YEAR ________ METAL CAST ______________

PERIOD	MELT TONS	SHIPPED TONS	HEAT TREAT TONS	SALES VALUE
JANUARY				
FEBRUARY				
MARCH				
APRIL				
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				
TOTALS				

AVERAGE MELT TONS/DAY = ______________

REPORTED % SCRAP ______________

REPORTED % MELT LOSS ______________

AVERAGE FOUNDRY YIELD % ______________

FORM 4-6

PLANT EQUIPMENT HORSEPOWER LIST

EQUIPMENT	TYPE	CAPACITY	OPERATION		H.P.	KW	SERVICE
			HRS/DAY	DAYS/MO			

FORM 4-7

DESCRIPTION AND FLOW RATES OF GAS-FIRED EQUIPMENT

EQUIPMENT	TYPE	BURNERS		OPERATION		AVERAGE CFH	MAXIMUM CFH
		NO.	TYPE	HRS/DAY	DAYS/MO		
TOTALS							

FORM 4-8

PRESENT ENERGY-EFFICIENCY RECORD

MONTH OR YEAR RECORDED				______
UNITS OF PRODUCTION				______
FUEL COSTS				
• Electricity				$ ______
• Natural Gas				______
• Propane				______
• Oil				______
• Coke				______
• Other				______
		TOTAL		______
ENERGY USED				
• KWH ______	x	3,412 Btu	=	______ Btu x 10^6
• Mcf Gas ______	x		1/	______
• Gal. Propane ______	x	91,600 Btu	=	______
• Gal. Oil ______	x	140,000 Btu	=	______
• Coke - lb. ______	x	12,500 Btu	=	______
•			=	______
		TOTAL BTU		______

ENERGY USED PER UNIT OF PRODUCTION

$\frac{\text{(Million Btu)}}{\text{(Units)}}$ = ______ Btu x 10^6/Ton

COST PER MILLION BTU

$\frac{\text{(Energy Cost)}}{\text{(Million Btu)}}$ = ______ Cost/Btu x 10^6

COST PER UNIT OF PRODUCTION

$\frac{\text{(Total Cost)}}{\text{(Units)}}$ = ______ Cost/Unit

1/ 1 Mcf = 1,000 cu.ft./hr - See Gas Bill for Btu content/cu.ft.

FORM 4-9

POTENTIAL ENERGY-EFFICIENCY RECORD

MONTH OR YEAR RECORDED ____________________

UNITS OF PRODUCTION ____________________

FUEL COSTS

- Electricity $ ____________________
- Natural Gas ____________________
- Propane ____________________
- Oil ____________________
- Coke ____________________
- Other ____________________

TOTAL ____________________

ENERGY USED

- KWH ________ x 3,412 Btu = ____________________ Btu x 10^6
- Mcf Gas ________ x 1/ ____________________
- Gal. Propane ________ x 91,600 Btu = ____________________
- Gal. Oil ________ x 140,000 Btu = ____________________
- Coke - lb. ________ x 12,500 Btu = ____________________
- = ____________________

TOTAL BTU ____________________

ENERGY USED PER UNIT OF PRODUCTION

$\frac{\text{(Million Btu)}}{\text{(Units)}}$ ____________________ = ____________________ Btu x 10^6/Ton

COST PER MILLION BTU

$\frac{\text{(Energy Cost)}}{\text{(Million Btu)}}$ ____________________ = ____________________ Cost/Btu x 10^6

COST PER UNIT OF PRODUCTION

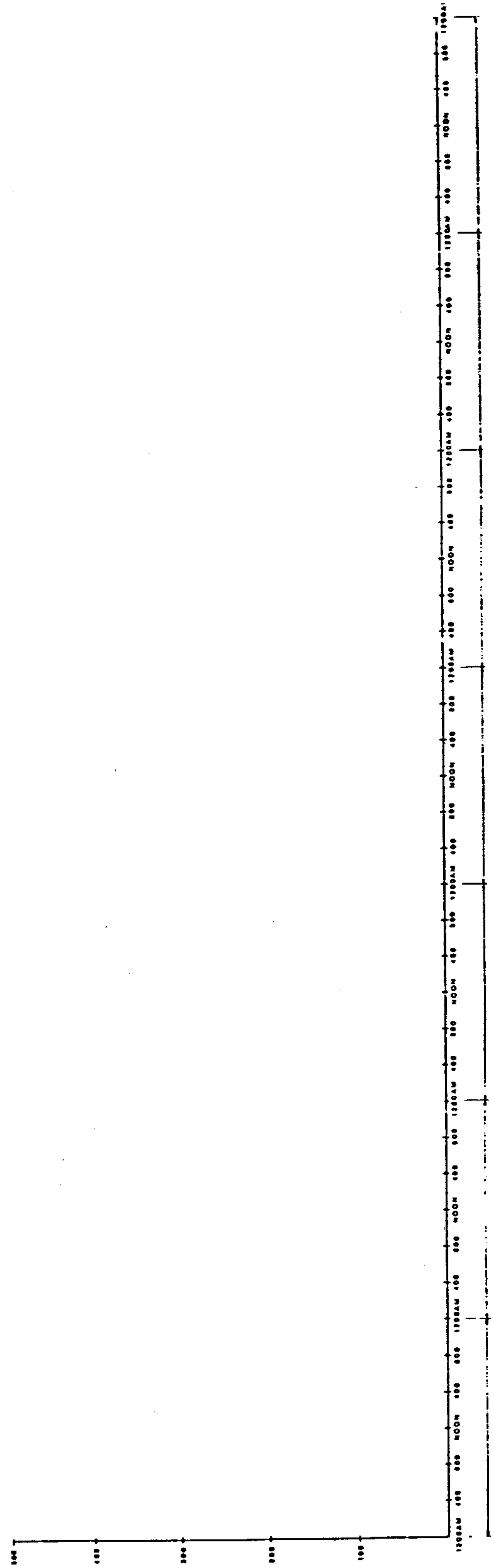
$\frac{\text{(Total Cost)}}{\text{(Units)}}$ ____________________ = ____________________ Cost/Unit

1/ 1 Mcf = 1,000 cu.ft./hr - See Gas Bill for Btu content/cu.ft.

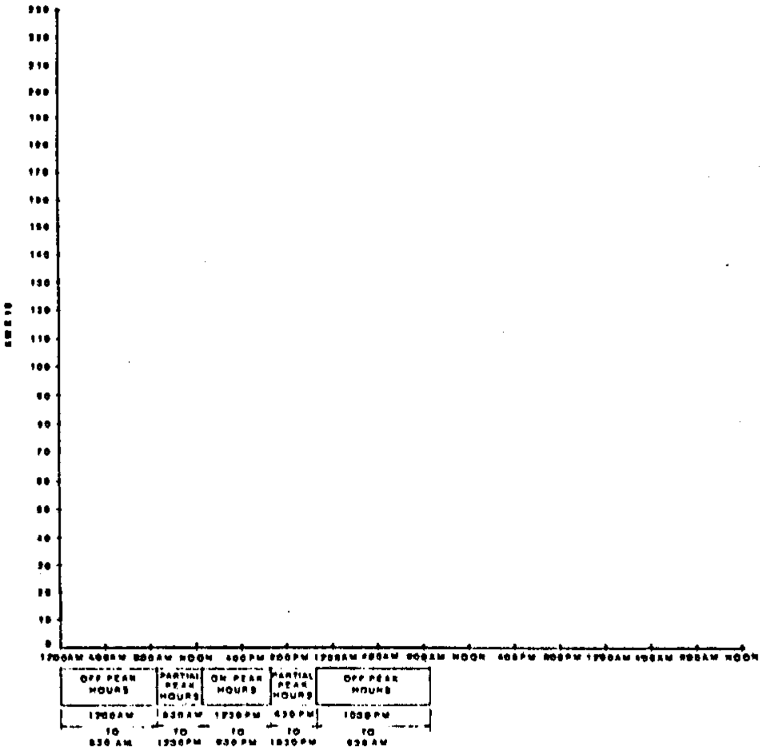
FORM 4-10

B. OPERATIONAL DATA FACT SHEETS

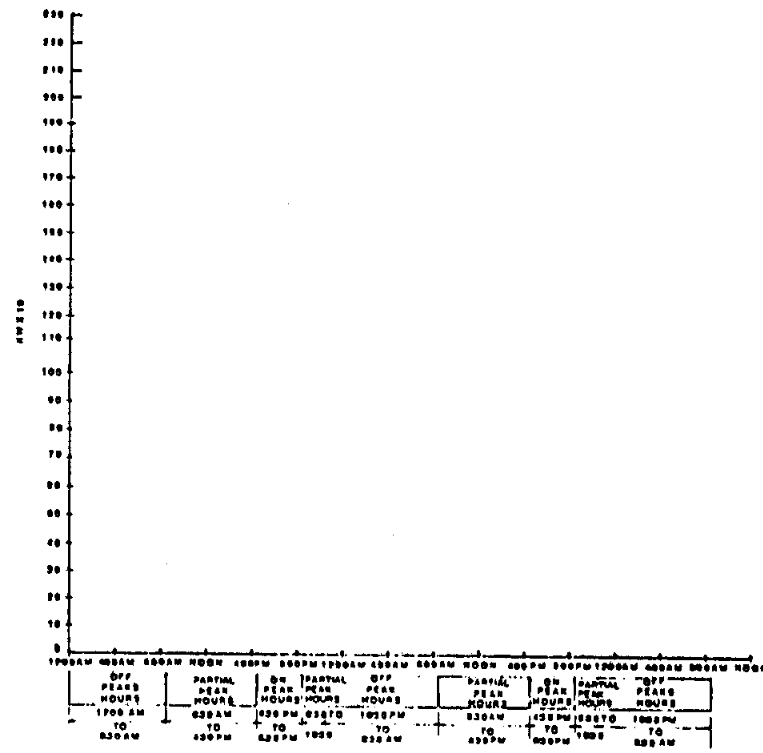
KILOWATT DEMAND LOAD PROFILE



FORM 4-11



KILOWATT DEMAND PROFILE (SUMMER)



KILOWATT DEMAND LOAD PROFILE (WINTER)

FORM 4-12

OPERATIONAL DATA FACT SHEET

ARC FURNACE DATA

Furnace make______________

Model_____________________

Shell Dia.___________FEET

Bath Depth_________INCHES

Capacity_____________TONS

Electrode Dia.___________inches

Transformer________________KVA

Primary___________________Volt

Taps 1st__________________Volt

2nd__________________Volt

3rd__________________Volt

Output________________Ton/YR

Alloy_______________________

Melt cycle__________minutes

Heat size___________tons

Heats per day______________

Temperature_________°F

No. of Back charges________

No. of slag cycles_________

Blow down cycle 0_2_________minutes

Type of fume collection:

Furnace pressure___________oz

Exhaust____________________CFM

Water Cooling______________GPM

Roof________, Glan________, Slag Door________, Bazel________,

Water temperature in________°F, out___________of

Type of refractory lining.

REMARKS:

Form 4-13

OPERATIONAL DATA FACT SHEET

CORELESS INDUCTION FURNACE

Furnace make________________ Transformer KVA________________

Model________________ Primary Voltage________________

Capacity________________ Secondary Voltage________________

Output________________tons/yr.

________________tons/day

Alloy________________

Melt cycle________________minutes

Tap Quantity________________lbs.

Charge Quantity________________lbs.

Tap temperature________________^{o}F

Holding temperature________________^{o}F

Slag cycle________________minutes

Fume collection________________CFM

Water cooling....GPM, Temp.........in ^{o}F.......Out ^{o}F

Type of Refractory________________

Energy consumption________________KWH/YR

Energy Cost________________¢/KW

REMARKS:

FORM 4-14

OPERATIONAL DATA FACT SHEET

GAS MELT FURNACE DATA

Metal type: ______________________ Annual tons ____________________

Pouring or tap temperature __________ °F

Heat content Btu/lb ________________ Shifts/day ____________________

Melting period hrs. ________________ Holding period hrs. ____________

METHOD OF MELTING	CRUCIBLE	REVERB
Metal melted/hr.lbs.	____________	____________
Burner rating Btu/hr	____________	____________
Total gas usage/hr	____________	____________
Capacity of furnace lbs.	____________	____________
Crucible diameter	____________	____________
Area of metal radiation sq.ft.	____________	____________
Area of refractory wall:		
Below metal	____________	____________
Above metal	____________	____________
Thickness of wall	____________	____________
Door open area or dip well sq.ft.	____________	____________
Mean temperature of walls °F	____________	____________
Outer temperature of walls T_1	____________	____________
Inner temperature of walls T_2	____________	____________
Present refractory K value	____________	____________
Proposed refractory K value	____________	____________
Rs value for refractory	____________	____________
CO_2 flue gas reading	____________	____________
Combustion air cfm	____________	____________
Combustion air wg	____________	____________
Flue gas (or comb.) temperature	____________	____________
Ambient temperature °F	____________	____________
Time of day used	____________	____________
Days/year used	____________	____________
Energy cost/therm $	____________	____________

FORM 4-15

OPERATIONAL DATA FACT SHEET

HEAT TREATING UNIT NO.	
FURNACE MAKE ________	BURNER MAKE ________
MODEL ________	MODEL ________
SIZE ________ WFT.	TYPE ______ SIZE ______ BTU/HR
CAPACITY ________ LBS.	FUEL ________
TYPE OF LINING ________	RECUPERATOR MAKE ________
WALL THICKNESS ________ INCH	MODEL ______ TEMP ______ °F
BLOWER MAKE ________	TYPE ______ SIZE ______
MODEL ________	CONTROLS MAKE ________
SIZE ______ CFM. PRESS ____ "WG	TYPE ________
VOLT ______ HP ______	

TYPE OF HEAT TREAT CYCLE ________	ALLOY ________
HEAT TREAT CYCLE - HEATUP ___ HRS	FUEL/AIR RATIO ________
- SOAK ___ HRS	FLUE TEMPERATURE HIGH ____ °F LOW ____ °F
-COOL DOWN ___ HRS	SHELL MEAN TEMPERATURE ______ °F
CYCLES PER WEEK ________	
TEMPERATURE ________ °F	FURNACE PRESSURE ______ "WC
AVERAGE LOAD ________ LBS	
CASTING ________ LBS	FLUE ANALYSIS (HIGH) ____ % CO
BASKETS ________ LBS	____ % O_2
STOOLS ________ LBS	____ % CO_2
LOAD DENSITY ________ LBS/WFT	LOW ____ % CO
QUENCH___ AIR,___ H20___ OIL	____ % O_2
QUENCH TEMPERATURE ______ °F	____ % CO_2
	FUEL CONSUMPTION THERMS/CYCLE

WALL AREA ________ SQ.FT.

WALL TEMPERATURE HOT FACE T_1 ________ °F

WALL TEMPERATURE COLD FACE T_2 ________ °F

AMBIENT TEMPERATURE ________ °F

EXTERNAL SURFACE AREA ________ SQ.FT.

ENERGY COST/THERM $________

HEAT TREAT LOADS/DAY ________

HEAT TREAT LOADS/YEAR ________

FORM 4-16

OPERATIONAL DATA FACT SHEET

BURN-OUT FURNACES

FURNACE MAKE ______ MODEL ______ SIZE ______ CAPACITY ______ LBS. TYPE OF LINING ______ EXHAUST BLOWER MAKE ______ MODEL ______ SIZE ______ CFM. PRESS ____ "WG VOLT ______ HP ______	BURNER MAKE ______ NO. OF BURNERS ______ TYPE ______ SIZE ______ BTU/HR FUEL ______ AFTER BURNER MAKE ______ MODEL ______ TYPE ______ SIZE ______ OPERATING HOURS MAIN BURNER ______ AFTER BURNER ______
TYPE OF FURNACE CYCLE ______ N/A ______	
FURNACE CYCLE - HEATUP ____ HRS - SOAK ____ HRS CYCLES PER WEEK ______ TEMPERATURE ______ LOAD DENSITY - ______	FUEL/AIR RATIO ______ FLUE TEMPERATURE HIGH ____ °F LOW ____ °F FURNACE PRESSURE ______ CO_2 IN FLUE GAS ______ FUEL CONSUMPTION ______ Therms/Day
REMARKS:	

FORM 4-17

OPERATIONAL DATA FACT SHEET

LADLE PREHEAT DATA

LADLE CAP TONS ________________ HEAT CYCLES/DAY ______________

LADLE AREA INSIDE ___________ SQ FT. LINING THICKNESS __________

COVERED ____________________ TYPE OF LINING ________________

INSIDE TEMP ______________ ^{o}F OUTER SHELL TEMP ____________ ^{o}F

AMBIENT TEMP ____ ^{o}F

GAS USAGE/HR ______________ CU FT. CO_2 READING _______________

COMBUSTION AIR _______________ CFM PRESSURE _______________ WG

PREHEAT CYCLE TIME ____________ HRS FLUE TEMP ______________ ^{o}F

REFRACTORY K VALUE _______________ RS VALUE ___________________

BLOWER HP ___________________ RECUPERATOR EFFCY _______________

FUEL COST/THERM $_______________ ANNUAL USE ___________ BTU x 10^6

NUMBER OF UNITS IN USE ____

REMARKS:

FORM 4-18

OPERATIONAL DATA FACT SHEET

CUPOLA DATA

CUPOLA DIA SHELL ________ INS REFRACTORY THICKNESS____________

LINING________ INS WATER COOLING GPM______________

HEIGHT OF TUYERES ABOVE HEARTH ______________________________ INS

LAUNDER LENGTH __________________________ WIDTH ________________

METAL TO COKE RATIO ________________ BED COKE ______________ LBS

MELT RATE ______________ TPH COKE ADDITION/HR __________ LBS

BLAST RATE _________________ CFM PRESSURE __________________ ONZ

NUMBER OF TUYERES __________________ DIAMETER ________________ IN

NUMBER OF ROWS OF TUYERES _________ SPACING _________________ IN

COOLING WATER USAGE _____________ GPM $T_1 - t_2$ _______________ ^0F

FAN HP ______________________ MISC. HP ___________________________

HOT BLAST TEMP __________ ^0F RECUPERATOR CAP _________BUT/HR

AFTER BURNER RATING BTU/HR _______________________________________

OXYGEN ENRICHMENT PERCENT ADDITION ___________________________ %

MELTING PERIOD; BLAST ON ___________ BLAST OFF _________________

COKE BREEZE ADDITION, PERCENT OF COKE _______________________ %

ANTHRACITE ADDITION, PERCENT OF COKE _______________________ %

<u>REMARKS</u>:

OPERATIONAL DATA FACT SHEET

HEAT TREAT FURNACES (ELECTRIC)

FURNACE MAKE ____________________ MODEL ______________

SIZE _____________ INSIDE _______________ OUTSIDE

CAPACITY _________ LBS. TYPE _____________________

WALL THICKNESS __________ TEMP. RANGE ___________ °F

HEATING ELEMENT ______ VOLTS ______ AMPS __________ kW

HEAT TREAT CYCLE - HEAT-UP ________ HRS

SOAK ________ HRS

COOL DOWN _____ HRS

CYCLES PER WEEK ___________________

ELECTRICAL CONSUMPTION _____________ KWH/CYCLE

REMARKS:

FORM 4-20

OPERATIONAL DATA FACT SHEET

GAS-FIRED SCRAP PREHEAT

METAL TYPE ________________ DENSITY ________________ LBS/CU.FT.

PREHEAT TEMPERATURE ____________ °F. CYCLE ________________ HRS

MELTING CAPACITY ____________ TONS/DAY. MELT RATE ________ TONS/HR

FUEL AVAILABLE FOR PREHEAT ____________________________ COST/THERM

CHARGE SIZE/WEIGHT PER BATCH ________________________________ LBS

PREHEAT BURNER RATING BTU/HR ____________________________________

CO_2 FLUE GAS READING _____________ TEMPERATURE ______________ °F

COMBUSTION AIR CFM _______________ PRESSURE _________________ WG

AMBIENT TEMPERATURE ______________ TIME OF DAY USED ______________

SHIFTS PER DAY __________________ DAYS/YEAR ____________________

REMARKS:

FORM 4-21

SECTION 5

ENERGY SAVINGS PROCEDURES CHECKLIST

Many energy savings opportunities exist in all foundries that can be instituted immediately without requiring large capital equipment investments. The checklist that follows presents these no cost/low cost energy savings ideas together with suggestion modifications and changes that will require medium to major capital investments:

	APPLIES	DOES NOT APPLY	COMMENTS
Infiltration--Infiltration of cold air into the plant through cracks, openings, gaps around doors and windows, etc., increases the building's heat load and may be responsible for 20 to 25 percent of the yearly space-heating energy consumption. This waste can be eliminated, and an additional saving in heating realized, by taking the following steps:			
__1. Replace broken or cracked window panes.			
__2. Caulk cracks around window and door frames.			
__3. Weatherstrip windows and doors.			
__4. Close windows while the building is being heated.			
__5. Check sealing gaskets and latches for all operable windows to see that they are working properly.			
__6. Close all rolling-type doors when they are not being used.			
__7. Eliminate unnecessary windows and skylights.			
Heating, Ventilating, and Air-Conditioning (HVAC) Systems--HVAC systems have a significant impact on the plant's total energy consumption. These changes in operational routine can cut HVAC energy use 5 to 15 percent:			
__1. Establish minimum temperature levels for the heating season and maximum levels for the cooling season. Establishing these levels requires consideration of occupied and unoccupied periods.			
__2. Repair or replace all damaged or defective thermostats or control equipment; calibrate as necessary.			
__3. Mount thermostats on inside walls and columns only.			
__4. Lock all thermostats to prevent unauthorized personnel from tampering with them.			
__5. Eliminate the use of mechanical cooling when the plant is unoccupied. Turn off heat or maintain a 50 F minimum in unoccupied areas.			
__6. Inspect all outside air dampers to ensure that they establish an air-tight fit when closed.			
__7. Establish startup and shutoff times for HVAC systems.			
__8. Shut off or adjust HVAC systems during weekends and holidays.			
__9. Minimize outdoor air intake.			

	APPLIES	DOES NOT APPLY	COMMENTS

Makeup-Air Units--Whenever air must be heated, inefficiencies are probable. The following modifications to makeup-air units can help conserve energy:

__1. Adjust burners for proper flame patterns.
__2. Clean burner nozzles periodically to remove mineral deposits and corrosion buildup.
__3. Observe the fire when the unit shuts down. A fire that does not cut off immediately could indicate a faulty control valve. Repair or replace the control valve as necessary.
__4. Keep all heat-exchanger surfaces clean.
__5. Inspect casings for air leaks. Seal them as necessary.
__6. Clean or replace air filters regularly.
__7. Keep fan blades clean.
__8. Inspect and lubricate motor bearing regularly.
__9. Inspect fan inlets and discharge screens to keep them free of dirt and debris at all times.

Insulation--Transmission heat losses and gains through walls, glass, roof, floor, etc., can be controlled with adequate insulation. The savings depend on the loss reductions achieved. A 5 to 10 percent saving is possible.

Lighting--Lighting represents a major portion of electrical energy use. A reasonable effort should be made to use only the amount of lighting necessary for safety and efficiency. Taking the following steps could lower plant electrical energy consumption approximately 5 to 15 percent:

__1. Use daylight for illumination when possible. Turn off lights when sufficient daylight is available.
__2. Turn off lights at night and in unoccupied areas during the day.
__3. Install simple timers on light switches throughout the plant, including in offices.
__4. Keep lighting equipment clean and in good working order.
__5. Replace burned out or darkened lamps and clean all fixtures.
__6. Increase the light-reflective quality of walls and ceilings with light colors. Such improvements may permit additional lighting reductions.

Boilers--In any boiler operation, the main source of energy waste is inefficient combustion. A 10 to 25 percent energy saving is possible by reularly following these simple checks and guidelines:

__1. Inspect boilers for scale deposits.
__2. Keep all heat-transfer surfaces as clean as possible to reduce temperature differences.
__3. Follow the boiler manufacturer's recommendations.
__4. Follow the feedwater treatment and blowdown procedures recommended by the supplier. This measure will save fuel by minimizing scale formation.
__5. Inspect door seals and other seal gaskets. Leaking gaskets waste fuel; doors may be deformed.
__6. Check boiler stack temperature. If it is too high (more than 150 to 200 deg F above steam temperature), clean the tubes and adjust the burner.

	APPLIES	DOES NOT APPLY	COMMENTS

__7. Adjust the burner so that the stacks are free of haze.
__8. Collect and analyze flue gas samples regularly to determine if combustion is efficient.
__9. Minimize the amount of excess air supplied for combustion.
__10. Operate only one boiler unless it cannot supply the load.
__11. Prevent short-cycle firing.

Steam Lines and Traps--Whether small or large, the leaks in steam piping, fittings, valves, and traps add up and can waste large amounts of energy. A detailed survey of all such piping should be made weekly or monthly and the following steps should be taken:

__1. Repair or replace defective or missing insulation.
__2. Inspect steam traps and replace those that are worn, inoperative, or improperly sized.
__3. Inspect pressure-reducing and regulating valves and their related equipment. Adjust, repair, or replace as necessary.
__4. Check pressure gauges and thermometers for recording accuracy.

Fans, Pumps, and Motors--Proper maintenance of fans, pumps, and motors can significantly improve their operational efficiency. The following steps can save energy at almost no cost:

Fans:
__1. Clean the blades.
__2. Inspect and lubricate bearings regularly.
__3. Inspect belts for proper tension.
__4. Keep inlet and discharge screens free of dirt and debris.

Pumps:
__1. Check packings for wear. Bad packings waste water and erode the shaft.
__2. Inspect bearings and belts regularly.

Motors:
__1. Keep motors clean.
__2. Prevent overvoltage and undervoltage.
__3. Eliminate excessive vibration.
__4. Correct loose connections, bad contacts, belts, pulleys, bearings, etc.
__5. Check for overheating and provide adequate ventilation.
__6. Prevent imbalance in power phase sources. This condition can cause inefficient motor operation.

Domestic Hot and Cold Water--Following these guidelines can maximize the efficiency of domestic water use:

__1. Inspect the water supply system and repair leaks, especially faucet leaks.
__2. Inspect insulation on storage tanks and piping. Repair as needed.
__3. Turn off the pump when the building is unoccupied, if hot water is distributed by forced circulation.
__4. Inspect and test hot-water controls. Regulate, repair, or replace as necessary.
__5. Disconnect all refrigerated water fountains, if acceptable to building occupants.

	APPLIES	DOES NOT APPLY	COMMENTS

Compressed Air Systems

__1. Install either solenoid valves or remote operated valves on assembly line air mains to eliminate normal or accidental air leaks during non-operating hours.

__2. Avoid utilizing expensive city water for a once through compressor cooling system. Instead, investigate recycling cooling water through a cooling tower.

__3. Investigate utilizing waste air compressor aftercooler cooling water (95-115°F.) as boiler make up. This both saves the energy that would be required to heat city water from 55° to 95° and reduces the waste water discharged to city sewers with a resultant sewer charge reduction. As a rule of thumb, this will result in a 2 gallon fuel oil saving per 1000 gallons of make up water.

__4. Install solenoid valves on all machine air supply lines to limit air use to actual machine operating periods.

__5. If large quantities of low pressure compressed air are required, consider installing a separate low pressure compressor rather than reducing from the main plant supply.

__6. Be sure the compressed air intake is in a cool location. Every 5°F. drop in intake air temperature results in a 1% increase in compressed air volume for the same compressor horsepower requirements.

__7. Extra air receivers at points of high periodic air demand may permit operation without extra air compressor capacity.

__8. Keep compressor valves in good condition for maximum efficiency (worn valves can easily reduce compressor efficiency 50%). Many compressor manufacturers recommend removal and inspection every 6 months.

__9. Match compressor pressure to actual system requirements. Operating a compressed air system at higher than requiered pressure results in higher compressor maintenance and reduced efficiency, as well as increased operating costs. Most air tools are designed to operate with 90 PSI at the tool. Higher pressures result in increased maintenance and shorter tool life expectancy. Typically, a 10% increase in pressure will reduce tool life about 14%.

__10. Size air hoses for minimal pressure drop to air tools. For instance, a tool designed to operate on 90 PSI will operate on 80 PSI, but at a 15% reduction in production.

__11. Consider the installation of double acting water cooled piston compressors rather than rotary screw compressors if the compressor will be operating at partial load much of the time. A double acting water cooled piston compressor requires as little as 5-7% of full load horsepower when unloaded, while a rotary screw compressor can require as much as 60-75% of full load horsepower when unloaded.

	APPLIES	DOES NOT APPLY	COMMENTS
__12. Locate and repair all piping leaks. Typically, many manufacturing plants lose about 10% of their compressed air through leaks, usually from loose pipe fittings, valve packing, shut off valves, worn out filters-regulators-lubricators, quick couplers, and unused air tools. A 1/16" leak can waste 6.5 cfm, and in addition to wasting compressor horsepower, will cost @ $8.00 per month. The hundreds of leaks in many industrial air systems can represent a tremendous energy waste.			
__13. Be careful to size compressor capacity fairly closely to load, since a compressor's efficiency is highest at full load.			
__14. Consider the installation of several smaller compressors rather than one large unit. Sequential operation will enable each compressor to operate at full load.			
__15. Prohibit all use of compressed air operated fans or compressed air hoses for personal cooling.			
__16. Remember that it requires about 1 horsepower to produce 5 CFM @ 100 PSI while a 1 horsepower vane type air motor requires about 25 CFM @ 90 PSI. Investigate replacing high usage air motors with electric motors where practical.			
__17. Consider using solenoid valves to cycle punch press blow off nozzles for only a short interval. Many blow off nozzles have a 1/8" orifice and, if operated continuously, will consume about 25 CFM @ 100 PSI (the equivalent of 5 HP compressor).			
__18. Consider reducing the operating speed/pressure on air operated paint pumps and paint agitators during off-shift hours. Depending on pigmentation and metallic content it may even be possible to stop all agitation or circulation of some enamels or lacquers during off hours.			
__19. In addition to poor partial load mechanical efficiency, induction type compressor motors have extremely poor power factors at reduced outputs. For instance, a 250 HP induction motor has a .87 PF at full load and a .55 PF at 1/4 load. Significant low load operation can drastically raise utility power factor charges.			
__20. For highest efficiency, be sure air tools are kept in good repair and are not excessively worn. For instance, a sand blast nozzle worn from 5/16" to a new diameter of 3/8" would consume an additional 65-70 CFM.			
__21. Minimize low load compressor operation. If air demand is less than 50% of compressor capacity, consider converting smaller compressors from constant speed operation to start/stop operation.			
__22. Install timers on desiccant type compressed air dryers to match dryer recharging cycles to actual system requirements.			
__23. Match compressor operation to building hours. A time switch can permit close control of compressor hours and permit shut down of high unloaded horsepower compressors during meal breaks or shift changes.			

Welding Operations	APPLIES	DOES NOT APPLY	COMMENTS
__1. Investigate converting heating equipment fuel from acetylene, natural gas, or propane to methylacetylene propadiene, stabilized (MAPP). This gas may reuslt in the improved performance, higher cutting speeds and reduced oxygen consumption.			
__2. If product design is applicable, consider utilizing seam welding (RSEW) instead of coated electrode metal arc welding (SMAW), metallic inert-gas welding (GMAW), or submerged arc welding (SAW). Since high frequency seam welding only heats the actual welding zone, distortion is minimized. The process is also less energy intensive than most other applicable welding processes.			
__3. Consider utilizing electronic precipitators to "scrub" welding exhaust fumes and thereby eliminate building exhaust with its attendant heat loss.			
__4. Install solenoid valves on welder or water cooled torch supply lines to limit cooling water flow to actual welder operating periods.			
__5. Consider the installation of smoke detectors to control welding exhaust fans.			
__6. Investigate inerta welding for uniform tubular or solid sections and similar shapes. Inerta welding can often replace alternative welding methods with their related preparatory machining operation.			
__7. Investigate using bag type dust collectors/filters to reduce building exhaust.			
__8. If welding shop workload varies widely, investigate ordering any new transformer type welders with built-in power factor correcting capacitors.			
__9. If oxy-acetylene welding/cutting torches are frequently used throughout the day, consider installing weight actuated automatic torch valves. This should help insure that an unused torch is turned off when it is hung up.			
__10. Investigate the installation of automatic cutting torches, which normally operate at maximum speed, thus yielding maximum cutting for minimum gas consumption. Their cutting speed and accuracy can often replace more energy intensive alternative manufacturing methods.			
__11. Be sure gas welding equipment connections and hoses are tight. Leaks both waste expensive gas and are fire hazards.			
__12. Investigate using high frequency induction heating for brazing operations instead of hand-held torch or a furnace.			
__13. Consider operating automatic cutting torches on natural gas or propane instead of acetylene. Acetylene has a higher flame temperature than normally required for steel cutting.			
__14. Consider using hot air instead of direct gas flame soldering torches. Since hot air is supplied at lower temperatures, it conserves energy and improves product apperance, as well as reducing fire hazards.			
__15. Replace continuous pilot lights for gas welding torches with conventional flint lighters.			

	APPLIES	DOES NOT APPLY	COMMENTS

__16. Be careful to avoid over-welding, either during design or manufacture.

__17. Use flame gouging instead of chipping hammers to remove tack welds, full welds, defects, blow holes, or sand inclusions.

__18. Consider using flame deseaming or scarfing instead of chipping hammers to remove cracks, seams, scabs, and crowsfeet. Hot scarfing can clean up forgings without the cooling and reheating required by chipping.

__19. In general, transformer type arc welders are more energy efficient than motor-generator welders. At full rated load, transformer type welders will consume slightly less power than a comparable motor-generator welder. At partial or no load, however, motor generator efficiency and power factor drop appreciably.

__20. Motor generator welders are valuable where ripple-free DC is required from single phase power. A transformer-rectifier welder cannot normally deliver well filtered DC from single phase power.

__21. Investigate "stack cutting" with automatic cutting torches. In many cases, a thicker cut uses proportionately less oxygen per piece than a thinner cut. Cutting accuracy is a maximum below 2" total thickness and gradually deteriorates until the normal maximum cutting thickness of 6" is attained.

__22. Shut down transformer type and motor-generator arc welders when not in use and during breaks and lunch. Savings will be minimal with transformer type welders but will become increasingly significant when motor-generator welders are stopped.

__23. Be sure unused automatic torches are turned off when not in use. Avoid excessive idle time.

Process and Manufacturing Operations

__1. Evaluate all machine tool purchases carefully for operating efficiency. In some cases, an alternative manufacturing method may result in lower energy usage per piece.

__2. Consider installing electrostatic precipitators to minimize dust or particle exhaust, such as from welding operations.

__3. Investigate installing smoke detectors to operate exhaust fans.

__4. Interlock process ventilation equipment with the equipment it serves.

__5. Replace simplex or duplex steam pumps with motor driven pumps where feasible.

__6. Install timers on punch presses, press brakes, and hydraulic pressses to shut down equipment if left idling for more than 10-12 minutes.

__7. Install solenoid valves on all machine air supply lines to limit air use to machine operating periods.

__8. Investigate using mechanical methods, such as a cam or solenoid to eject punch press parts instead of using compressed air.

__9. Install either automatic doors or insulated flaps on conveyor type heat treating ovens to reduce heat loss.

APPLIES | DOES NOT APPLY | COMMENTS

__10. Install solenoid valves on all water cooled equipment water lines to minimize water leakage.

__11. Redesign processes to eliminate process exhaust ventilation.

__12. Investigate the installation of reflecting shielding or thermal barriers around heat treating equipment to minimize cooling load on adjacent areas, particularly in metallurgical laboratories.

__13. All water pumping equipment will have to operate at less than full design flow, consider the installation of variable speed pumps to minimize reduced flow power consumption.

__14. Avoid severely oversizing production equipment. An oversized tool is normally heavier and requires more power than a smaller, correctly sized tool.

__15. Operate air tools on correct pressure. Most air tools are designed to operate on 90 PSI. Tool operation on lower pressures reduces output, while only a 10 pound pressure increase results in a 14% tool life expectancy reduction.

__16. Meter unusual gas or process chemical requirements. "Billing" a department for actual consumption can often result in phenomonal consumption reductions.

__17. Modify product test or analysis procedures to avoid high energy consumption tests. For instance, minimize test time on engine operated equipment.

__18. Investigate the feasibility of operating production machinery at 100% load for one shift rather than at partial load for two shifts. For instance, careful scheduling of vapor degreaser opeation may permit full load operation for fewer hours.

__19. Attempt to reduce machine idle time as much as feasible to maintain high power factors.

__20. Assign specific plant personnel to be sure all production equipment is shut down after shift and during breaks and lunch.

__21. Operate melt furnace exhausts only during furnace charging or fluxing if feasible.

__22. Shut down process ventilation, building exhaust, and dust collection during breaks and lunch.

__23. If heat treating ovens are not required for immediate use, energy can be saved by reverting to a reduced temperature condition. Investigate constructing a cool down/reheat time chart for various furnace temperature. This will enable operating personnel to easily reduce furnace temperatures and still be able to have the furnace up to heat by the desired time.

__24. Consider operating heat treating ovens 24 hours/day to make maximum usage of energy.

__25. Use fixed cycle times for heat treating/annealing operations. Many actual oven times are far longer than actually required, with a resulting energy waste.

__26. Operate chip conveyors only when needed, not continuously.

	APPLIES	DOES NOT APPLY	COMMENTS

__27. Avoid partial heat treating furnace loads.

__28. Shift or combine operations for both reduced building hours and improved machine utilization.

__29. Minimize leaks and overflow from heated process tanks.

Material Handling and Transportation Systems

__1. Install "bump through" doors in fork lift areas to reduce open door time.

__2. Install a flexible covering, such as rubber or canvas strip, over scrap conveyor openings in building walls.

__3. Shrouds should be used in all dock doors when possible. Investigate using air curtain fans if shrouds are not available.

__4. Investigate installation of "air pallets". In some cases, they can offer energy reductions compared to lift trucks, particularly where an oddly shaped work piece must be moved short distances at slow speeds.

__5. Be sure fork lift air cleaners are clean. Some high dust locations may require centrifugal pre-cleaners to prolong filter element life.

__6. Be sure to purchase fork lift fuel that meets the manufacturers standards. Bargain fuel can actually reduce operating efficiency.

__7. In a large operation, consider the installation of two-way radio equipment on material handling equipment to reduce the number of empty return trips. Try to schedule several moves for fork lifts in an area to maximize productivity.

__8. Consider purchasing diesel fueled fork lifts. Their reduced fuel consumption and lower maintenance should result in substantial savings over gasoline or propane lifts.

__9. Investigate replacing internal combustion fork lifts with electric fork lifts. In many cases, operating costs (and energy consumption) will be lower. In some cases maintenace costs may drop up to 30%. Electric trucks also have lower downtime, are non-polluting, and are quieter.

__10. Consider installing electrical hoists rather than air operated hoists since a "1 horsepower" air hoist requires about 5 compressor horsepower, while a "1 horsepower" electric hoist requires only 1 horsepower.

__11. Replace old, out-moded (and inefficient) motor-generator electric fork lift battery chargers with new, solid state, power factor corrected high efficiency battery chargers.

__12. Avoid pushing loads. Though this only wastes fuel and wears clutches with an engine operated truck, it can severely damage a battery operated lift truck's drive motor.

__13. Install overspeed governors on all internal combustion material handling equipment, particularly fork lifts, to eliminate empolyee hot rodding.

__14. Investigate fork lift records or contact manufacturers to discover the best fork lift fuel consumption. Log all machine fuel to determine operator errors or machine deterioration.

	APPLIES	DOES NOT APPLY	COMMENTS

__15. Be careful not to overfill fork lift fuel tanks. Spilled gasoline or diesel fuel or vented LPG is both wasteful and hazardous.

__16. If a light load has to be moved a short distance, use a hand truck rather than a fork lift. Be sure fork lifts are used for material handling, not personal transportation.

__17. Be sure pneumatic fork lift tires are properly inflated. Underinflation both damages tires and wastes fuel.

__18. Avoid using a far larger fork lift then required. For instance, use a 2000 pound lift to maneuver oil barrels rather than a 6000 pound lift.

__19. Avoid excessive fork lift idling. Start a lift only when there is work to be done - and stop it as soon as it is completed.

__20. Avoid making a habit of using a drastically oversized crane for a drastically undersized load. If a machine frequently requires a crane to load small work pieces, consider installing a small jib crane with an electric hoist. This both frees up the main crane for heavier jobs and saves energy.

__21. Install automatic timers to shut down crane motor generators if no crane moves are made within ten minutes.

Paint Line Operations

__1. Consider use of airless spray instead of air spray paint application. While it requires about 9.5 HP to atomize 1 GPM using air spray, it only requires about 1.3 HP to atomize 1 GPM using airless spray. Airless spray is particularly suited to large, heavy work pieces that must be painted with one coat, in place, such as heavy construction equipment, barges, structural steel, or railroad cars.

__2. Since natural gas is a decreasing resource, investigate the applicability of ultra-violet cured metal finishes to your product. Frequently, product redesign may enable the use of ultra-violet post coating or may permit using pre-coated coil stock. In many cases, coil coating uses only about 20% of the energy required for post painting.

__3. Consider installation of direct fired paint ovens instead of indirect fired. The heat transfer coefficient for dirct fired is about 97% versus 60% for indirect fired, with comparable differences in fuel consumption.

__4. Investigate conversion to water base painting materials. Water base usually cuts energy consumption by reducing spray booth air flow, oven exhaust, air makeup requirements, and oven times. In some cases, finishing lines have reudced total natural gas consumption up to 45%.

__5. Research is currently being done to develop low temperature cure and air dry waterbase coatings. Current future forecasts often predict water base may account for up to 60% of the industrial finishing market by 1985.

__6. Consider utilizing gas fired washer combustion products to provide heat for dry off oven. This would be paricularly applicable to direct fired washers.

	APPLIES	DOES NOT APPLY	COMMENTS
__7. If your product configuration is applicable, consider converting to a high intensity infra-red curing which uses as little as 10% of the energy required for a comparable gas fired oven.			
__8. Investigate converting paint ovens to the "Raw Oven Exhaust Recycle Process". This system returns part of the oven exhaust back to the oven after passing through an incinerator.			
__9. Investigate conversion to airless paint drying from conventional oven baking. This system holds oven oxygen content to as low as 1%, with resulting reductions in oven exhaust and gas requirements.			
__10. Reduce spray booth/makeup air temperature to 65° - 68°.			
__11. Investigate installing electric ovens instead of gas or oil fired. Higher operating costs are somewhat reduced by better temperature control, constant one-fuel operation, and more readily controlable oven atmosphere.			
__12. Consider insulating the entire paint line parts washer to reduce heat loss. Some plant operators estimate they have achieved up to 20% fuel reduction in metal pretreatment operations after insulating parts washers.			
__13. If insulating the entire washer is not feasible, investigate insulating the heated portion of the washer.			
__14. Consider additional paint oven wall insulation. Doubling the present thickness (usually only 2") will cut wall losses in half. Since most paint oven heat is lost through oven roofs, this portion in particular should be well insulated.			
__15. Consider utilizing ambient temperature solvent flash off if possible. In many casses, a slightly longer or slower conveyor may be all that is required.			
__16. Considerable heat is lost through oven "air seals", which are generally ineffective. Consider installation of bottom entry/exit oven, which better retain heated air within the oven.			
__17. Consider installations of oil fired paint ovens instead of gas fired. New oven technology can minimize paint discoloration and soot problems if a light, low sulfur (1%), oil is used.			
__18. Consider heat recovery equipment, such as "heat pipes", in spray booth and bake oven stacks. If heat recovery equipment is used, a regular maintenance program is required to minimize heat losses caused by paint residue build up.			
__19. Consider switching to low or ambient temperature parts washer cleaners and phosphating compounds. For instance, iron phosphates are now being successfully used at 100-120°F. in some applications.			
__20. Investigate staging spray booth air flow. If painters work only in the first section, with automatic spray equipment in the remaining zones, the booth air can flow into the first zone, and be exhausted to the other zones. In many cases, solvent concentration in the final zone would still be below the 25% LFL limit.			

Go To MAIN MENU

	APPLIES	DOES NOT APPLY	COMMENTS

__21. Replacing manual spray with automatic paint spraying machinery may permit a reduction in spray booth air velocity with a resultant make up air reduction. Material flammability and toxicity must be investigated to determine if any reductions are feasible. This normally requires approval from insurance inspectors, fire inspectors, O.S.H.A., and any other applicable agencies.

__22. Investigate using process steam condensate as heat source for paint line parts washer tanks.

__23. Use a fixed orifice rather than an adjustable valve to meter water into process or paint line constant overflow tanks for minimum flow.

__24. Check booth velocity carefully to avoid over exhausting. Consider using electrostatic spray since this usually permits a reduction of booth velocity of about 40%.

__25. Investigate interlocking paint line conveyors with parts washers and bake ovens.

__26. Investigate the feasibility of operating fume incinerators at reduced temperatures.

__27. If paint line or process exhausts include extremly high solvent concentrations, investigate recovering and re-refining these otherwise wasted solvents. In some cases, solvents have been reclaimed at an energy cost 1/5 - 1/6 the price of new solvent.

__28. Be sure plant is not occasionally under negative pressure. Negative pressure can starve gas burners resulting in a fuel rich flame with excess CO. Negative pressure also results in increased air infusion through walls and windows, with resulting cold drafts and worker complaints.

__29. Be sure all stages in a process are really necessary. In some applications, washer stages may be eliminated or partially shut down, as may dry off ovens.

__30. If batch ovens are used, maximize loading and optimize working hours for highest energy efficiency. Similarly, minimize warm up time as much as possible.

__31. Because solvents are increasingly scarce and expensive, consider filtering, distilling, or otherwise recycling solvent.

__32. It may be possible to improve paint oven heat transfer by increasing circulating air velocities or volume and by utilizing heating system radiant energy. Improved heat transfer may permit increased travel speeds with resulting increases in production with little or no increase in fuel reuqirements.

__33. Sequentially shut down ovens at end of shift or production run.

__34. Attempt to schedule all paint line operations for one shift if feasible.

__35. Be sure all gas immersion tubes used for liquid heating are clean (both interior and exterior) for best heat transfer.

__36. Be sure all air filters are kept clean.

__37. Change paint line conveyor speed and hook configuation as required with product changes to maximize productivity and minimize oven idle time.

__38. Reduce conveyor speed when parts are not flowing through wash or bake ovens.